DOCUMENT RESUME

ED 179 809 CE 023 586

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TITLE Automotive Fuel Economy: A Technical Study and Curriculum Development Project. A Thesis Presented to the Faculty of the College of Education, Mankato State University.
PUB DATE Mar 79
NOTE 171p.; Ph.D. Dissertation, Mankato State University

EDRS PRICE MF01/PC07 Plus Postage.
DESCRIPTORS *Auto Mechanics; Course Content; *Curriculum Development; *Curriculum Guides; Energy Conservation; *Fuel Consumption; Mechanics (Process); *Motor Vehicles; Postsecondary Education; Technical Education; Technology; Testing

ABSTRACT

Automotive fuel economy was the topic of a study during which technical and background information was gathered, curriculum materials were sought, and curricula were developed. Technical information came from written materials and actual mileage tests of selected factors. Background came from written materials, field trips, and building and running of project cars in fuel economy tests. While a great deal of technical information exists on fuel economy, no curriculum materials could be found, despite intensive search. Hence, materials were developed at four levels: (1) a one-hour presentation for general audiences; (2) a three-contact-hour general presentation for use in a basic automotive mechanics course; (3) a three-contact-hour specific presentation on fuel economy testing for a "gasoline engine technology" course; and (4) a three-credit course on fuel economy testing to be used as an in-service program for teachers on the secondary and postsecondary levels. (Basic curriculum materials, mileage test forms, and test results are appended.) (CP)

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AUTOMOTIVE FUEL ECONOMY: A TECHNICAL STUDY AND CURRICULUM DEVELOPMENT PROJECT

A Thesis Presented to

the Faculty of the College of Education

Mankato State University

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In Partial Fulfillment

of the Requirements for the Degree

Specialist in Curriculum and Instruction:

Industrial Education

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by

Kirk Lewis Ready

March 1979

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Abstract

AUTOMOTIVE FUEL ECONOMY: A TECHNICAL STUDY
AND CURRICULUM DEVELOPMENT PROJECT

Kirk Lewis Ready
Specialist in Curriculum and Instruction:
Industrial Education
Mankato State University, 1979

The study was conducted to examine the topic of automotive fuel economy and to develop related curriculum materials to be used in a typical automotive technology program. The direct application of the materials was intended for use in the automotive courses offered by the Industrial Technical Studies Department at Mankato State University.

The project was divided into three stages. Technical information was reviewed, curriculum information was sought, and then curriculum materials were developed.

The study reported on the technical information related to fuel economy and also recounted the research project vehicles that had been constructed and tested at Mankato State University.

No usable curriculum material was found in the review of literature. Based on this finding, a four stage curriculum was developed which included a one hour general presentation, a three hour general instructional unit, a three hour specific instructional unit on economy testing, and a three credit in-service course.

Date February 26, 1979

This independent study project has been supervised, examined and approved.

Advisory Committee:

Richard B Davis Chairman

Gordon Rainie

William R. Schmeck

ACKNOWLEGEMENTS

The writer would like to thank the many students at Mankato State University who aided in the study of fuel economy, built project vehicles and participated in the economy competitions. Without their efforts and enthusiasm, this study would not have been feasible.

TABLE OF CONTENTS

Chapter		Page
1.	INTRODUCTION	1
	The Problem	1
	Statement of the Problem	1
	Importance of the Study	2
	Definitions of Terms Used	4
	Organization of Remainder of Thesis	5
	Limitations of the Study	6
2.	REVIEW OF THE LITERATURE	7
	Technical Materials	7
	Historical Background	8
	Test Procedures	8
	Test Results	8
	Government Regulation	9
	Mankato State University Projects	9
	Curriculum Materials	9
	Computer Search	10
	Search One	10
	Search Two and Three	10
	Search Four	11
	Summary	11
3.	FACTORS AFFECTING FUEL ECONOMY	12
	The Driving Cycle	12

Chapter Page

Route Planning 13
Warm-Up/Idling 13
Mixed Traffic Driving 14
Open Traffic Driving 14
The Car 14
Car Selection Factors 15
Car Maintenance Factors 18
The Environment 20
Summary 21
4. MEASURING FUEL ECONOMY 22
Units of Fuel Economy 22
Miles Per Gallon (mpg) 22
Ton Miles Per Gallon (tmpg) 23
Passenger Miles Per Gallon (pmpg) 23
Kilometers Per Liter (km/l) 24
British Thermal Units Per Mile (BTU/Mile) 25
Specific Fuel Consumption (SFC) 26
Brake Thermal Efficiency (BET) 28
Cost Per Mile (¢/mile) 28
Methods of Fuel Economy Measurement 29
Distance Measurement 30
Fuel Measurement 31
Variables Affecting Fuel Economy Test Results 37
Weather 37
Driver 38
Vehicle 38

Chapter Page

Course 39
Summary 39
5. FUEL ECONOMY TEST PROCEDURE AND RESULTS 40
Test Procedure 40
The Cars 40
The Course 42
Fuel Measurement 43
Control of Variables 43
Test Sequence 44
Test Result Calculation and Summary 45
Test Results 46
Error Determination - Test #1 46
Air Cleaner Reversal - Test #2 46
Vehicle Speed - Test #3 47
Power Steering - Test #4 47
Window Position - Test #5 48
Tire Pressure - Test #6 48
Air Conditioning - Test #7 49
Extra Weight - Test #8 49
Tire Size - Test #9 50
Overdrive - Test #10 50
Summary 51
6. A REVIEW OF MANKATO STATE UNIVERSITY ECONOMY PROJECTS 52
The 50/50 Experimental Economy Vehicle (EEV) 53
The Beginning 53
The Goal 53

Chapter Page

The Vehicle and Modifications 54
The Tests 56
The Spirit of 76 MPG 59
The Beginning 59
The Goal 60
The Vehicle and Modifications 61
The Tests 63
The Bradley GT 64
The Lancia Beta Coupe 65
Future Vehicle Research 66
7. GOVERNMENTAL REGULATION OF FUEL ECONOMY 68
Legislative History 69
The Law 71
Automotive Regulations: Title III (PL94-163) 71
Automotive Regulations: United States Code 73
Automotive Regulations: Secretary of Transportation . . . 74
Automotive Regulations: Environmental Protection Agency 75
Progress and Possibilities 76
Summary 77
8. FUEL ECONOMY CURRICULUM 79
General Audience 79
Audience Background 79
Length of Presentation 79
Method of Instruction 80
Objectives 80
Topics 80

Chapter Page

Audience Activities 81
Demonstrations 81
Teaching Aids 81
Evaluation Procedure 81
Basic Automotive Mechanics, ITS 231 82
Audience Background 82
Length of Presentation 82
Method of Instruction 82
Objectives 83
Topics 83
Student Activities 84
Demonstrations 85
Teaching Aids 85
Evaluation Procedure 85
Gasoline Engine Technology, ITS 431, 531 86
Audience Background 86
Length of Presentation 86
Method of Instruction 86
Objectives 87
Topics 87
Student Activities 88
Demonstrations 88
Teaching Aids 89
Evaluation Procedure 89
In-Service: Fuel Economy Testing, ITS 491, 591 90
Audience Background 90

Chapter Page

Length of Presentation 90
Method of Instruction 90
Objectives 91
Topics 91
Student Activities 92
Demonstrations 92
Teaching Aids 92
Evaluation Procedure 93
Summary 93
9. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS 95
Research Methodology 95
Findings and Conclusions 96
Recommendations 96
REFERENCES CITED 97
APPENDIXES
A. MILEAGE TEST FORMS AND RESULTS 101
B. CURRICULUM MATERIALS 147
C. SLIDES 157

Chapter 1

INTRODUCTION

An examination of Automotive Technology curriculum revealed a variety of course titles with many topics related to the repair and maintenance of current day vehicles. Some of the courses also covered topics of consumer interest such as buying used cars and automotive insurances. Other courses went into technical topics which often included dynamometer testing, exhaust emissions, or performance modifications of engines. One area which did not seem to be included in most courses was the topic of fuel economy. Many courses covered tune-up, lubrication, engine rebuilding, or diagnosis. Each of these topics may have included various areas of fuel economy, but the topic of fuel economy by itself was not found. Fuel economy was a significant aspect of the automotive field and, with the advent of the energy crisis, deserved to be covered as a separate topic in automotive courses at any level of instruction.

I. The Problem

Statement of the Problem

This study was conducted to develop a set of teaching units and associated packages of instructional materials on the topic, "Fuel Economy of Passenger Vehicles". The units were to be based on fuel economy research conducted on the various factors which could affect the overall operating efficiency of a vehicle. The unit and its associated instructional materials were intended to be made available for use in

any one of a variety of individual automotive courses which make up the typical Automotive Technology curriculum of an educational institution. The materials were to be suitable for use by secondary schools, vocational schools, community colleges, and universities offering course work in the field of Automotive Technology.

While the teaching unit was the end product of the study, a large percentage of the research time and effort dealt with the technology of fuel economy. After working with fuel economy technology for several years, the production of the teaching unit became mainly a task of sorting out information on the topic and putting it into a presentable format for instructional purposes.

Importance of the Study

While much information was available on the topic of fuel economy, a review of the literature on the topic did not reveal any publications or materials which were intended for use in an instructional or laboratory setting. This void prompted the development of such materials.

The importance of the topic, "Fuel Economy" from the economic viewpoint was obvious to all consumers who paid between sixty and seventy-five cents per gallon for gasoline. Many average families have spent over $1,500 every year just to fuel their vehicles. Cars have served the American society in many ways, ranging from pure utility to status symbols, but to most people the private automobile was a necessity for the average family. Transportation figures showed that, considering all forms of passenger transportation, private automobiles accounted for more than 86 percent of all passenger miles produced in the United States (12:24).

The importance of the topic, "Fuel Economy" from the viewpoint of energy conservation and the depletion of natural resources was also

obvious. While it was tied in with the economic situation (supply vs. demand vs. cost), the problem was greater than that. Various experts had many predictions on the exact date the last gallon of oil will be pumped out of the earth, but they all agreed the day will come. In 1974, the private automobile was the largest single user of energy in our entire society (36:243). In 1975, the United States consumed about 80,000,000,000,000,000 British Thermal Units of primary energy, and of this amount, transportation used slightly over one-fourth of that total (17:15-16). Figures showed that as of July 1, 1977, there were 97,818,221 passenger cars registered for use in the United States (7:50). That figure was growing yearly, with nearly 10 million new cars sold each year in the model years 1972 through 1977 (7:46). With about one car for each two people in our country, it was apparent that a significant place to attack the energy problem was the private automobile.

Based on the assumption that most Americans will have a personal car, the question of fuel economy came down to several factors.

1) How much did we drive? The total number of miles was a major consideration.

2) How did we drive? Drive habits and such things as the fifty-five mile per hour speed limit had a large effect on fuel efficiency per mile traveled.

3) What did we drive? The size, weight, engine efficiency and options of a present day automobile each put limits on the possible fuel efficiency of any given vehicle.

The solution to the fuel economy situation was to drive a minimun number of miles, using good driving techniques, at the most efficient speed, in a vehicle as small and light weight as possible, with the best

available engine and options for maximum operating efficiency. This solution, however, required many compromises which a large number of people were not willing to make. Part of the problem was that many individuals did not know what alternatives were available which lead to better fuel economy, or what compromises could be made and what their net effects would be. If gasoline prices went up to two dollars per gallon within the next year, most people would have been willing to make more sacrifices to achieve better fuel economy. But, where would they have started? What could have been done? These were questions which the teaching unit on "Fuel Economy of Passenger Automobiles" attempted to answer. With a problem facing us, and the alternatives beside us, we would be able to make decisions, plot a course of action, and have a good chance of finding a workable solution with which we could live.

II. Definitions of Terms Used

The terms listed here were limited to the scope of this chapter and the overall premise of this paper. Technical terminology was defined as an integral part of the chapters where such terminology appeared.

Automotive technology curriculum. A course or group of individual courses dealing with the technical aspects of automotive maintenance and repair, and also including consumer information on the various aspects of owning an automobile. The curriculum may range from junior high school age through adult education and includes both vocational and industrial education-type courses at the secondary and post-secondary level. The term does not generally include driver education but for the purposes of this paper, it could be included.

Teaching unit. An organized group of materials and information on a discreet topic. A unit consists of objectives, outlines, instructor notes, and resource information, plans for student activities, handout sheets or textbook readings, reviews of available audio-visual materials, teaching aids, displays or models, instructor prepared visual materials, evaluation tools, and a bibliography. Each unit may not necessarily make use of all of these items.

Fuel economy. Miles per gallon were used in this paper. The importance of the metric system was realized, as well as relationships to units of heat commonly used in energy calculations. At several points in the paper, miles per gallon were related to kilometers per litre or BTU's or Calories; but the majority of the time, fuel economy of vehicles was related in miles per gallon figures.

III. Organization of Remainder of Thesis

The remainder of this paper began with a review of available literature from two viewpoints. Fuel economy curriculum materials were reviewed separately from the technical and related information on the topic.

Technical information included an analysis of the various factors affecting fuel consumption, methods of measurement, and a reporting of actual test data from fuel economy research conducted by the author.

Related information included a review of experimental economy vehicle projects at Mankato State University, and a review of government regulation of fuel economy.

The paper concluded with a curriculum proposal showing a number of ways this topic can be included with existing automobile technology

curricula at various levels. Shown as an example is the program at Mankato State University.

IV. Limitations of the Study

Fuel economy technology was changing quickly. Economic considerations, energy depletion, and government regulations all helped speed up and direct the changes. Materials presented in this paper must be updated by any individual wishing to use it as an aid for instruction. Without this updating process, the information will surely become obsolete and inaccurate in a short time.

Another limitation was found in the fuel economy test results. Availability and accuracy of the test equipment used and the choice of vehicles was limited. The tests were done on only a selected number of factors and were repeated a limited number of times. These factors reflect upon the overall reliability of the test results and their comprehensiveness.

Finally, the curriculum proposed may not fit, as intended, to each and every automotive course. Some modification will necessarily be required by individuals using this information in their own teaching situations, with regard to objectives of the course, time available for the course, level of instruction, space, and equipment available.

Chapter 2

REVIEW OF THE LITERATURE

The review of the literature took place over an extended period of time and was divided into two specific areas. Technical information was reviewed first because it was to be the basis for the formulation of test procedures and the selection of fuel economy topics to be evaluated in the study. Second, a search for curriculum materials, in the topic area of fuel economy, was conducted.

To reduce the general subject of fuel economy to a more workable and relevant topic, the search was specifically conducted on automobile fuel economy and associated curriculum materials. Descriptors, such as engines, motor vehicles, fuel consumption, automobiles, and transportation, were used to locate technical information and information on course content, course objectives, curriculum guides, technical education, performance criteria, job skills, and other materials related to curriculum.

The result of the search was a deluge of technical information and a drought of curriculum materials.

In addition to the manual search, a computer search was undertaken on three data bases, SAE Abstracts, National Technical Information Service, and Educational Resource Information Center.

I. Technical Materials

The many aspects of fuel economy led the review in this section into numerous areas and sources.

Historical Background

Information in this area was researched by using newspapers. Items of national importance were found in the New York Times, while subjects related to the State of Minnesota were examined through the Minneapolis Tribune. Both of these sources provided the public viewpoint of such events as the 1973 Arab Oil Embargo and the various national energy plans, including the lowering of the speed limit by each of the 50 states to 55 miles per hour. The news, as it was seen by the automotive industry, was found in the weekly newspaper, Automotive News.

Test Procedures

Techniques, equipment, and procedures used to measure fuel economy were found in a variety of locations. Technical bulletins and procedure sheets form the Society of Automotive Engineers, and the American Society for Testing and Materials, were used along with information provided by various consumer related magazines, which test and report on automotive fuel economy. Instruction manuals provided by manufacturers of gasoline mileage and related scientific measurement equipment were also used.

Test Results

The reports on fuel economy testing of various factors were found in three major sources. First, and least factual, was information obtained from manufacturers of devices and products which were intended to increase fuel economy. Second, reports published in consumer related magazines, such as Popular Science or Motor Trend, provided some general information. The last, and most factual source, was technical reports published by the Society of Automotive Engineers.

Government Regulation

Laws, rules, and regulations which pertained to automotive fuel consumption were located in the Congressional Record along with the United States Code Annotated. These two major sources, in addition to the reporting of the results of the legislation by the public press, provided the necessary legal information. No information was found related to state or local laws.

Mankato State University Projects

Information on this area was taken from the author's personal notes and newspaper and magazine articles which covered the various events and projects in which the University was involved.

II. Curriculum Materials

The search in this area was conducted by reviewing textbooks, curriculum guides, college catalogs, and publications from the automotive industry.

Textbooks on auto mechanics were checked for content. After looking at twenty-two current and outdated books, none was found to have a chapter on fuel economy, and very few listed the term in the index. Where it was listed, the term usually referred to the fuel system and various carburetor adjustment procedures.

Curriculum guides from public schools were examined and once again, fuel economy was found to be neither a separate course nor a major unit within a course. Mention of mileage, if found at all, was listed as a sub-topic of the fuel system.

College catalogs from institutions offering an automotive

curriculum were examined for courses that may have been based around fuel economy. None was found.

The last area considered for available curriculum material was publications and course offerings from the automotive industry. While several bulletins and pamphlets were located, they provided only technical information.

III. Computer Search

A computer search was undertaken to provide additional information of both a technical and a curricular nature. Four separate searches were made using three data bases.

Search One

The first search was performed on the SAE Abstracts covering the years 1965 to 1975. The category code names used were "fuel economy" and "passenger cars". This search located 67 citations and abstracts. After a review of the abstracts, 32 of the citations were ordered through the Mankato State University Library-Media System to be put on file for future reference and research work. All citations were technical in nature and none mentioned curriculum.

Search Two and Three

Both the second and third searches were performed on the National Technical Information Service data base (NTIS). The first trial used "fuel economy" and "passenger vehicles" as descriptors. This yielded 33 entries. Then, "all automobiles" was added as a descriptor to the two descriptors previously used. This showed 253 more entries. From that list, the first 30 entries, which were the latest additions, were printed

out. Upon review of this information, it was found that eight of the citations had already been found in the author's manual search. In addition to these eight, ten more were ordered through the Mankato State University Library-Media System to be put on file for future reference and research work. All citations were technical in nature and none mentioned curriculum.

Search Four

The final search was performed on the Educational Resource Information Center data base (ERIC). When using the descriptors "fuel consumption", "motor vehicles", and "curriculum", no citations were found. Then when the descriptor "curriculum" was removed, five citations were found. A careful analysis of the abstract showed that two of the citations concerned the curriculum of the Dade County, Florida public schools quinmester program in automotive mechanics. While fuel economy was mentioned in the abstract, it was only included with a tune-up unit along with emission standards. Copies of the curriculum guide were obtained, but they revealed no further specific information on curriculum associated with fuel economy, or fuel economy testing.

IV. Summary

Technical information on fuel economy was in abundance. It was found in many formats and from many sources. Curriculum information, however, was virtually non-existent.

Chapter 3

FACTORS AFFECTING FUEL ECONOMY

There were a limited number of factors which affected fuel economy in an automobile. If the goal was to improve the fuel economy, any possible gains came from the affecting factors. Nothing was gained from thin air. No magic improved gas mileage. With this in mind, it became apparent that the factors affecting fuel economy were identified and used as a starting point in the search for more miles per gallon.

A number of different categories or groups of factors were available. One logical choice divided fuel economy factors into three major groups: the driving cycle, the car, and the environment. Any change in gas mileage, up or down, was attributed to one or a combination of these three factors.

I. The Driving Cycle

This category was made up of two distinctly different but yet interrelated areas. The driver himself had much to do with how the vehicle was driven, but he contended with constraints such as traffic flow, destination, available roads and all laws, rules and regulations which governed his actions.

The Environmental Protection Agency defined, for the purpose of exhaust emission and fuel economy testing, an average driving cycle as one which had seven and one-half miles of stop-and-go driving at an average speed of twenty miles per hour, and ten miles of non-stop highway

driving at an average speed of 50 miles per hour (41:8). In addition the Agency estimated that 55 percent of all vehicle travel involved city driving while the remaining 45 percent involved highway driving.

The Environmental Protection Agency's test was not used as a pattern for personal driving, but it provided an equitable method for evaluating and comparing the test vehicle's standard performance. For test purposes, personal driving cycles were broken down into four sections: route planning, warm-up/idling, mixed traffic driving, and open traffic driving.

Route Planning

The planning of the route was a function of the driver but he was limited in his choices by where he went and what routes were available to get him there. It was the driver's decision which route was best. This was true whether the trip was of the 4,000 mile cross-country type or the short multi-stop around town shopping trip. Proper route planning affected total fuel consumption in two ways. First, and most important, it reduced the total number of miles traveled. This did not improve the miles per gallon but saved fuel. Second, a given route yielded more miles per gallon if it had less traffic, more constant speed, fewer stops, or less hills.

Warm-Up/Idling

While this was a minor portion of the driving cycle, it was very important. When a car was not moving it was getting zero miles per gallon and that became difficult to balance out. The driving cycle in this case was controlled by the driver and it was his decision on how long to let the car warm-up and idle without turning off the engine.

Mixed Traffic Driving

The condition of stop-and-go driving in mixed traffic was one that yielded poor fuel economy but nad to be considered. Proper route planning helped minimize this type of driving, but it could not eliminate it. When operating in mixed traffic, the driver made a great difference.

Open Traffic Driving

Open traffic driving had more potential for good fuel economy than did the mixed traffic driving, but once again, the driver was responsible for making proper use of the opportunity. Speed and smoothness were the key elements to this form of driving. Most vehicles achieved their maximum fuel economy at a steady rate of 30 to 40 miles per hour (44:41). While driving down the freeway at 35 miles per hour was not practical, speed was inversely related to fuel economy. Smoothness was also an important factor. Any change in speed required extra energy consumption.

Overall, the driving cycle, and especially the driver's contribution to it, made major differences in the fuel economy of a vehicle. In addition, when compared to the car or the environment, the driving cycle was the easiest factor to deal with in order to make positive changes immediately and at little or no cost.

II. The Car

Next to the driving cycle, the car was the most important factor affecting fuel economy. Driver decisions and action, once again, played a major role. Theoretically the driver chose not only the car, but also chose how that car was maintained.

Car Selection Factors

The most important factor in the car's fuel consumption was its weight (44:17). Heavier cars required more energy to climb hills, accelerate, and overcome rolling resistance. The Environmental Protection Agency showed that a 500 pound gain in weight tended to reduce fuel economy by between two to five miles per gallon, while a 2,500 pound car tended to get twice the gas mileage of one weighing 5,000 pounds (40:10). The penalty for buying a large, heavy car was less severe if most driving was at highway speeds. Stop-and-go operation showed the biggest difference in fuel consumption between large and small cars.

The engine size and type also had a major affect on fuel economy. When two cars were otherwise equal, the one with the smaller engine almost always was more economical to operate (44:19). Conventional engines were most efficient when operating at a high percentage of their full power. The smaller engine worked harder and thus delivered better fuel economy. The type of engine also was a fuel economy factor. The Wankel rotary engine delivered 20 to 35 percent less fuel economy while the Diesel produced 40 to 70 percent more (40:21).

There were a number of options on a typical car which affected fuel economy. The selection of transmission type was an example. Automatic transmissions, while less work to operate, yielded poorer fuel economy than standard transmissions. The addition of overdrive to the standard transmissions yielded even better results.

Along with transmission selection, the rear axle ratio choice was important. A high gear ratio (numerically low) meant less engine wear, slower acceleration, and more miles per gallon than a low gear ratio. For example, a high ratio of 2.73:1 allowed the engine to turn more slowly at

70 miles per hour than a lower ratio of 3.90:1 turned at 50 miles per hour (44:22).

Road Speed (mph)	Car A 2.73 axle (rpm)	Car B 3.90 axle (rpm)
30	1140	1630
40	1520	2170
50	1900	2710
60	2280	3260
70	2660	3800

While vehicle weight, engine size, transmission type, and axle ratio all had major affects on fuel economy potential there were a number of items which, by themselves, had only a small effect but when grouped together added up to a considerable difference in economy. Any power accessories decreased mileage to some extent. Power brakes, steering, seats and windows used a small amount of energy but their major drawback is the weight, up to 30 pounds for each, that they added to the car. Air conditioning, which weighed about 100 pounds, also used a considerable amount of energy when used and reduced fuel economy by several miles per gallon. The affect of all these accessories was felt most in stop-and-go driving and driving at the lower speeds. As the car went faster the affect of increased air resistance tended to overshadow other factors.

Automatic speed controls helped improve fuel economy of a poor driver, but did little to improve the mileage of the good driver. By using the best of driving techniques, it was often possible to obtain better fuel economy without the aid of speed control.

Tire selection played an important role in economy. Radial tires not only produced better fuel economy, but they also lasted longer. Oversize tires provided a larger rolling diameter which gave the effect of a higher axle ratio. This gain was partially offset by the additional weight

of the larger tires.

Disc brakes were superior to the drum variety in many ways but they created a small amount of friction. This friction reduced fuel economy. However, the loss was small, and the other benefits such as less fade and better moisture resistance were the reason disc brakes became standard equipment on most new cars.

Electronic ignition was standard on most new cars and was retrofitted to older models which had the conventional ignition system. There was no immediate advantage to the electronic system with regard to fuel economy. A well-tuned conventional system equaled the results of the electronic type. However, as the conventional system started to wear, the critical settings of point gap and ignition timing began to change. At about 10,000 miles the system needed maintenance and if the system was not properly maintained, the gas mileage began to drop. The electronic system, on the other hand, kept its peak efficiency for up to 25,000 miles and then normally only needed service to the spark plugs. Fuel saved depended on the owner's maintenance intervals. Another savings was money not spent on the overall maintenance of the vehicle.

The basic shape of a vehicle affected its fuel economy. While it was true that for a given type of car, most manufacturers built similar shapes, the buyer of the car was able to eliminate choices such as permanent roof racks and large oversize mirrors from his option list if he was looking for good fuel economy.

Color affected the heat absorbtion of the vehicle. Dark colors absorbed heat and kept the car warmer, whereas light colors and tinted windows helped reflect this heat. Thus, light colors saved some use of, or eliminated the need for air conditioning. The result was better mileage.

The fuel tank size did not affect mile per gallon ratings but a large tank allowed one to buy gasoline at a generally lower price and therefore reduced the cost per mile.

In addition to the better cost per mile, the large tank meant fewer stops on long trips. With fewer stops one was able to travel at a slower rate of speed and still get to the destination at the same time. The slower speed saved gasoline. A disadvantage of the large gas tank was the extra weight of the gas being carried.

In all, there were many individual decisions to consider when choosing a car for good fuel economy. Careful attention was paid to each factor in order to arrive at a workable package that had the needed utility and an acceptable level of fuel economy.

Car Maintenance Factors

Once the car was selected, the next choice the owner made was maintenance of the vehicle. The areas of lubrication and tune-up needed normal attention. However, in addition, there were several items that deserved more consideration.

The oil used in modern cars was a much better product than in the past. The oil flowed into the engine's moving parts and provided a cushion between these parts. Also, the oil helped cool the engine and removed contamination in the form of dirt, metals and acids. When choosing oil for a car, two factors affecting mileage should be considered. First, the viscosity of the oil was important. If it were too low the engine was damaged and if it were too high it created more friction and caused a loss of fuel economy. Multi-viscosity oil was specially formulated to be less affected by temperature than the single viscosity oil. Therefore, it protected the engine when hot as if it were a high viscosity oil but did not

thicken as much when cooled, thus reducing friction on a cold engine. The lower viscosity and the multi-viscosity oils offered potential for improved fuel economy.

Consideration was given to the new synthetic oils. In addition to offering very high levels of engine protection they also were very slippery, resulting in lower friction and higher fuel economy. Their cost, however, was quite high, but was expected to drop as more competition appeared on the market. Offsetting the high cost of synthetic oil was the advantage that it did not need to be changed as often as the petroleum based oils.

The ignition system, electronic or conventional, deserved special attention for good fuel economy. Few modifications, if any, were legal in most states, but a properly tuned system usually out-performed the system the owner modified. Ignition timing was the most critical factor in the tune-up and it was checked at frequent intervals and adjusted if necessary. Also, spark plug condition was important to fuel economy. However, it was false economy to replace the plugs too often.

Proper tire inflation was an item car owners could check themselves but chose to neglect. Tires should be checked when cold and inflated to the pressure recommended by the car manufacturer or to the maximum pressure shown on the side wall of the tire. Underinflation created excessive friction which lowered fuel economy and also damaged the tire because of heat build-up. Overinflation tended to make the tire tread wear out in the center. A tire which was underinflated by ten pounds per square inch caused a noticeable drop in fuel economy while a tire overinflated by the same amount showed very little if any gain. The car owner should have his own, good quality, tire pressure gauge and the tires should be checked every several weeks and before long trips. A study by the

National Bureau of Standards showed that 45 percent of the gauges used by gas stations were off by at least three pounds per square inch (1:13). This clearly pointed out the need for the owner to have his own gauge.

For the car to deliver its potential mileage, all maintenance items must receive proper attention. The most essential items were proper lubricants, proper tune-up, and proper tire inflation. The owner must take the responsibility of keeping track of these areas and taking proper action.

III. The Environment

Many items in the environment affected the fuel economy of a vehicle. Unfortunately, the motorist had little, if any, control over these factors. The Environmental Protection Agency ran its tests for emissions and fuel economy in temperature controlled conditions from 68°F to 86°F (41:8). This was not matched in any realistic driving cycle but did tend to standardize the results. The only time environmental factors needed to be considered by the motorist was when making a mileage test. Notes were made of any factors which influenced the outcome of the test.

Summer temperatures were better for fuel economy than winter temperatures. Wind increased or decreased mileage. A direct crosswind reduced mileage because one steered into it slightly in order to go straight ahead. Rain or snow caused a loss of efficiency because the tires were always going uphill to climb over the wetness. Rough or loose road surfaces greatly lowered mileage as did driving in hilly terrain. Altitude, barometric pressure, and humidity also influenced the fuel economy of a vehicle.

The following was a Government estimate of the affect some of these conditions had on a typical passenger car capable of 20 miles per gallon

combined on the EPA test at 70°F (41:6):

Condition	% Change	MPG
Base test		20.0
18 mph headwind	-10%	18.0
18 mph crosswind	-1%	19.8
18 mph tailwind	+12%	22.4
Wet roads	-10%	18.0
Rough roads	-10%	18.0
Loose gravel road	-30%	14.0
Cold, 20°F	-6%	18.5

While the preceding figures do not provide data on high altitude, low barometric pressure or humidity, each of these factors tended to provide a rich air-to-fuel ratio to the engine. This rich mixture reduced fuel economy. Vehicles operating in high altitude areas were successfully modified to correct the air-fuel ratio which restored a large portion of the lost mileage.

IV. Summary

Factors which affected fuel economy were put into one of three categories: the driving cycle, the car, or the environment. In the first two categories the driver of the car had a large influence on what mileage the car obtained. The immediate way to improve fuel economy in any car dealt with driving habits and trip planning while the short term answer was proper vehicle maintenance. In the long term, the owner was left to select a car with fuel economy in mind. Short of moving to a warmer, flatter, less windy location there was little that anyone could do about the environment.

Chapter 4

MEASURING FUEL ECONOMY

In order to determine the effects of various factors on fuel economy, it was necessary to be able to measure that economy. The accuracy with which these measurements were made was of primary importance if evaluation and predictions were to be based on the data. A variety of units which could be used to measure fuel economy were available, as well as a number of measurement methods, each employing specific apparatus and equipment.

I. Units of Fuel Economy

The fuel economy of an automobile was usually listed in terms of miles per gallon. However, there were times when other units may have been more appropriate for the study being done. The purpose of assessing fuel economy was to have facts upon which to make decisions. In some cases, units other than miles per gallon would have worked better in the decision-making process.

Miles Per Gallon (mpg)

The most widely used and universally understood unit for fuel economy was miles per gallon. For most purposes it was also the best unit to use in the study of fuel economy. The calculation was easily made if one knew the accurate distance traveled in miles and the quantity of fuel used in gallons. The major limitation of this unit was found when fuels other than gasoline were used. Some alternative fuels were

not in the liquid state, while other fuels had a vastly different energy content per gallon; therefore, it was not useful when comparing the fuel economy of one car which burned alcohol with another car which used hydrogen. Another limitation was found when one tried to assess the ability to do a specific job such as moving a given weight or number of people. Even with its limitations, miles per gallon was the most widely used unit of fuel economy.

Formula: $mpg = \frac{\text{Distance (miles)}}{\text{Fuel used (gallons)}}$

Example: A car drives 345 miles and uses 18.5 gallons of fuel

$$mpg = \frac{345 \text{ miles}}{18.5 \text{ gallons}}$$

$$mpg = 18.65$$

Ton Miles Per Gallon (tmpg)

The relative comparison of two vehicles of different weight could often be best compared by using ton miles per gallon. In this unit credit was given for the weight moved in addition to the raw miles per gallon. A fuel economy of five mpg in a 50,000 pound truck (125 tmpg) would actually be far better than 50 mpg in a 3,000 pound compact car (60 tmpg).

Formula: $tmpg = \text{Weight (tons)} \times \frac{\text{Distance (miles)}}{\text{Fuel used (gallons)}}$

Example: The previous example with 345 miles and 18.5 gallons was applied to a car which weighed 4,000 pounds (two tons).

$$tmpg = 2 \text{ tons} \times \frac{345 \text{ miles}}{18.5 \text{ gallons}}$$

$$tmpg = 37.30$$

Passenger Miles Per Gallon (pmpg)

Another variation of the basic miles per gallon unit took into

account the number of passengers being transported. The passenger mile per gallon was sometimes useful when comparing various vehicle styles or forms of passenger transportation. A fully loaded six-passenger family car getting 15 mpg (90 pmpg) was more energy efficient than a two passenger sports car getting 35 mpg (70 pmpg).

Formula: $\text{pmpg} = \text{number of passengers} \times \frac{\text{Distance (miles)}}{\text{Fuel used (gallons)}}$

Example: The previous example with 345 miles and 18.5 gallons is applied to a car with four people.

$$\text{pmpg} = \text{four people} \times \frac{345 \text{ miles}}{18.5 \text{ gallons}}$$

$$\text{pmpg} = 74.60$$

Kilometers Per Liter (km/l)

As the United States gradually changes to the metric system we will eventually see the area of fuel economy measurement change to metric units. This should cause no problems other than individuals getting use to thinking in the new terms. Most people, given the conversion factor and a calculator, could compute the conversion, but very few could respond to an individual saying, "My compact car gets 10.5 km/l while driving on the highway, how does that compare with your car?" (Note: 10.5 km/l = 24.7 mpg)

There seemed to be no move in the metric direction when fuel economy was discussed. While it will happen some day, it seemed to not be in the near future. When it does happen, it should cause no major problems; but at the time of the study, the use of the metric system in fuel economy studies was an academic rather than practical question (24:33).

Formula: $km/l = \frac{\text{Distance (kilometers)}}{\text{Fuel used (liters)}}$

Example: A car drives 528 kilometers and uses 62.5 liters of fuel

$$km/l = \frac{528 \text{ kilometers}}{62.5 \text{ liters}}$$

$$km/l = 8.45$$

Conversion Factors: 1 mpg = .4251 km/l

1 km/l = 2.3522 mpg

Conversion Example: To convert our example from kmpl to mpg we would multiply the kmpl times the conversion factor of 2.3524

mpg = 8.45 km/l x 2.3524

mpg = 19.88

British Thermal Units Per Mile (BTU/Mile)

It was sometimes necessary to compare various fuels of different state (gas, liquid, solid), density and energy content per unit weight. A practical way to handle fuel economy calculations was to use the British Thermal Units per Mile. A British Thermal Unit (BTU) was defined as the amount of heat energy needed to raise the temperature of one pound of water by one degree Fahrenheit (18:95). Calculations using BTU/mile almost always dealt with the weight of fuel used and the BTU/pound energy content of the fuel. Using the BTU/mile calculation, we could compare the energy efficiency of one car using 25 pounds of gasoline per 100 miles (5142.25 BTU/mile) with another car using 50 pounds of alcohol per 100 miles (4878.5 BTU/mile). In this case, the car burning alcohol was the most efficient. While BTU/mile was not a well recognized mileage measurement, it was easy to convert this figure back to MPG of gasoline by knowing the BTU/mile of the vehicle (43:18). The car in the example using 25

pounds of gasoline per 100 miles would be equal to 24.6 miles per gallon. It should also be noted that other various forms of the energy content units were available. Some examples were the Ton BTU/mile, Passenger BTU/mile, or the metric equivalent which would be calories per kilometer.

Formula: $\text{BTU/mile} = \frac{\text{Fuel weight (lbs.)} \times \text{BTU/lb. (for fuel used)}}{\text{Distance (miles)}}$

Example: A car using liquid propane as a fuel (21,510 BTU/lb) burns up 20 lbs. of fuel while driving a distance of 150 miles.

$$\text{BTU/mile} = \frac{20 \text{ lbs.} \times 21{,}510 \text{ BTU/lb.}}{100 \text{ miles}}$$

$$\text{BTU/mile} = 4{,}302$$

Conversion Factor: $\text{Equivalent MPG (gasoline)} = \frac{\text{BTU/gal. (gasoline)}}{\text{BTU/mile}}$

Note: Gasoline = 126,540 BTU/gallon

Conversion Example: The car using liquid propane used 4,302 BTU per mile of energy. The equivalent energy consumption for gasoline would give a mileage of

$$\text{Equivalent mpg (gasoline)} = \frac{126{,}540}{4{,}302}$$

$$\text{Equivalent mpg (gasoline)} = 29.41$$

Energy Content: (43:19)

Hydrogen	61,003	BTU/lb
Propane (liquid)	21,510	"
Gasoline	20,569	"
Diesel Fuel	20,328	"
Methanol	9,757	"

Note: Figures may vary for specific forms of various fuels. Different publications may list slightly different values.

Specific Fuel Consumption (SFC)

The measurement of Specific Fuel Consumption was useful to determine the efficiency of engines of various sizes. A lawnmower engine would

use less fuel per hour of operation than would the family automobile; however, the automobile engine was probably more efficient considering the job it had to do. Specific Fuel Consumption was an economy measurement that took into account fuel used, time elapsed, and horsepower produced. It was stated in terms of pounds of fuel per horsepower-hour. The test must be run on a dynamometer (Appendix C, Figure 1) which was capable of measuring the engine's horsepower level and loading the engine for a constant horsepower (19:31).

Specific fuel consumption was often used to determine under what load an engine ran most efficiently. For a full sized car to drive down the road at 55 miles per hour might require 50 horsepower at the engine. A large V-8 engine may be able to produce this horsepower at a low load (partial throttle). A small four-cylinder engine may need to operate at a heavy load (wide-open throttle). To produce the 50 horsepower at a light load, the V-8 may have been operating at a poorer Specific Fuel Consumption than the four-cyclinder engine was at a heavy load. If this were true (it usually was), the four-cyclinder engine would use fewer pounds of fuel per hour to produce the 50 horsepower and therefore, operated at a higher miles per gallon.

Without the use of specific fuel consumption, it would be impossible to relate the efficiency of various sizes of engines which were capable of doing different jobs.

Formula: $$SFC = \frac{\text{Fuel used (pounds)}}{\text{Power (horsepower)} \times \text{Time (hours)}}$$

Example: An engine run on a dynamometer uses 14 pounds of fuel in two hours of operation while putting out a constant 25 horsepower.

$$SFC = \frac{14 \text{ lbs.}}{25 \text{ hp} \times 2 \text{ hours}}$$

$$SFC = .28 \text{ lbs/hp-hr}$$

Note:* There was no practical way to convert this figure into mile per gallon because it would not take into account the size of the vehicle.

Brake Thermal Efficiency (BET)

Brake thermal efficiency was the ratio between the heat energy contained in fuel to the power output developed by the engine (19:31). In a typical gasoline engine this rating was 20 to 25 percent. The remaining energy was lost through the heat in the exhaust, the heat in the cooling system, and through friction. The BTE rating of an engine was found by knowing the Specific Fuel Consumption, this rating must be obtained while the engine is being run on a dynamometer. The BTE ratings were often used to describe the difference between various forms of heat engines such as the Diesel, Wankel, turbine and gasoline.

Formula: (general) $BTE = \frac{\text{Energy output}}{\text{Energy input}} \times 100$

(specific) $BTE = \frac{2545}{SFC \times \text{Fuel's BTU's/lb}} \times 100$

Note: 1 HP = 2545 BTU = 746 watts

Example: A small engine is being tested on a dynamometer and is is putting out 3.1 horsepower. At this output the specific fuel consumption is .6 lbs. per horsepower-hour. The fuel being used is gasoline with an energy content of 20,569 BTU's/lb.

$$BTE = \frac{2545}{.6 \text{ lbs./hp-hr} \times 20{,}569 \text{ BTU/lb.}} \times 100$$

BTE = 20.6 percent

Cost Per Mile (¢/mile)

The most important personal factor for most individuals when it came to vehicle energy efficiency was the unit of cost per mile traveled. Comparisons of gasoline versus electric vehicles were often given in this unit. The cost per mile was determined by two factors; the cost of the

fuel per unit quantity and the distance the vehicle traveled on that amount of fuel. An automobile using regular gasoline at a cost of 60.9 cents/gallon and having a fuel economy of 20 miles per gallon had a cost per mile of 3.045 cents/mile. This was actually less expensive than driving a vehicle which could obtain 22 mpg but used premium fuel at a cost of 68.9 cents/gallon. The second car cost 3.132 cents/mile to operate even though it got two mpg better fuel economy.

When alternative fuels were discussed, the present cost per mile and the projected costs per mile became very important to the consumer. Hydrogen was very expensive on a cost per mile basis when compared to gasoline. However, in the future as our oil reserves run out, and if hydrogen becomes more readily available, the scales may tip to favor hydrogen on a cost per mile basis.

$$\text{Formula: Cost Per Mile} = \frac{\text{Fuel cost (¢/gallon)}}{\text{Mileage of vehicle (mpg)}}$$

Example: A sub-compact car can get 35 mpg on unleaded gasoline which can be purchased for 62.9 cents/gallon.

$$\text{Cost per mile} = \frac{62.9 \text{ cents/gallon}}{35 \text{ mpg}}$$

Cost per mile = 1.80 cents

Note: Formula will change if different units of energy are considered. Example: electricity

II. Methods of Fuel Economy Measurement

In order to be able to determine fuel economy one must know how far the vehicle traveled and how much fuel the vehicle consumed. Without an accurate measurement of those two variables no reasonable results could be obtained. There were also a number of other variables which had to be kept constant from test to test if the results were to be compared.

Distance Measurement

For most people, the car's odometer was the one practical way which they could determine how far they have traveled. The odometer was usually a revolving drum-type which measured in tenths of a mile (Appendix C, Figure 2). In distances over ten miles in length, the odometer will read less than one percent of the total and this was accurate enough for most testing. However, many odometers were not accurate. This could be caused by a number of reasons including tire size and inflation, gear ratios, or the odometer mechanism itself. Before any distance measurements are made in a vehicle, the odometer should be checked for accuracy, and if found to be inaccurate, an "Odometer Correction Factor" (OCF) should be determined. An OCF is a raw number which when multiplied by the actual odometer distance traveled will yield the true distance traveled.

To determine the OCF for a vehicle, the following method could be used:

1. Drive a section of road which is 10 miles long, use the roadside mile markers to determine this distance.

2. At the beginning and end of the 10 mile run, read and record odometer reading.

3. Use the following formula to determine odometer correction factor: $OCF = \frac{\text{True Miles}}{\text{Odometer Miles}}$

4. To determine the actual miles traveled on any trip, multiply odometer miles times the OCF.

5. If used to determine mpg, use the OCF to determine true miles before calculating mileage. Note - the following can affect OCF: a. Tire Pressure, b. Tire Wear, and c. Accuracy of 10 mile stretch.

An example of the OCF and its application would show a car passing a roadside marker 125 just as its odometer registered 17,154.5 miles. Ten miles later as marker 135 was passed the odometer read 17,164.8 miles. The true distance traveled was 10 miles but the odometer registered 10.3 miles. The OCF would be 10 (true miles) divided by 10.3 (odometer miles) and would equal .9708737. After a trip which was 145.3 miles on the odometer we would multiply the OCF (.970873) times the odometer miles (145.3) to determine the true distance traveled (141.1 miles). The true miles traveled would then be used to determine the miles per gallon for the trip.

When distance measurements must be made with more accuracy than we could find on the odometer, the most practical alternative was to establish a set course upon which all mileage tests would be done. This course could then be accurately measured for distance and during testing no recording of odometer readings would be necessary.

This method worked well when many different vehicles were being tested, such as in Motor Trend magazine's mileage evaluations where they used a pre-set course which was 73 miles long (30:10). Another time when a pre-set course worked well was when the total length of the test was short, such as found in the three Mankato State University test courses which were 1.112 miles, 10 miles, and 27.94 miles long respectively. The shorter the course, the greater was the necessity to have an accurate distance measurement.

Fuel Measurement

The measurement of fuel used was as important as the distance measurement and was usually more difficult to obtain. The average individual would use the gallons figure on the gas pump as his fuel

measurement. This was not a bad method but it had two major drawbacks. First, the pump read to one-tenth of a gallon. This was a substantial amount of fuel on any short test run. It could amount to several percent. Secondly, the probability of filling the tank evenly each time was very low. It could vary by several gallons on some cars and could be influenced by how level the car sat while it was being filled. A minor problem with the gas pump was that as the temperature of the fuel varied so did the energy content. This, however, was not a great problem. The temperature of the gas never got as cold or as hot as the air temperature. The gas, held in an underground tank, maintained a fairly constant temperature.

If the gas pump was used to determine fuel consumed, several things could be done to achieve better accuracy. First, some stations had converted to a new pump style which has an electronic display for the gallons. This display showed the gallons to the hundredth instead of tenth of a gallon. An alternative method to obtain one-hundredth of a gallon accuracy was the cost method. In this method instead of reading the gallons off the pump display you read the cost per gallon and the total cost. By dividing the total cost by the cost per gallon you could determine the gallons to an accuracy of 1/120 of a gallon. This allowed the use of gallons to two decimal places as was found with the electronic display pumps. For example, if one filled the gas tank with gas at 63.9 cents per gallon, and the total cost was $10.43, one would divide $10.43 by $.639/gallon and find that 16.32 gallons of gas were used. There was no need to consider or record the gallons figure on the pump.

For more precise fuel measurement, especially on short test run mileage experiments, the gas pump, fill the tank methods did not work.

Three general methods that worked involved either weighing the fuel on a scale, measuring the volume with a burette, or measuring fuel flow with a meter placed in the fuel line.

The weight method worked very well and gave excellent results. It was easy to weigh small quantities of fuel to one-tenth of a gram accuracy on a common laboratory scale (Appendix C, Figure 3). This was equivalent to approximately .00003 gallons. Even using one ounce of weight provided accuracy to better than .01 gallons. The problem with the weight method remained on how to fill the tank to a constant level. This can be facilitated by the addition of a small auxiliary gas tank for use in test runs (Appendix C, Figure 4). The tank can be mounted in an upright and easy to fill position. The complete tank could then be removed and weighed. The fuel could also be weighed in a gas can, then poured into the tank, and after reweighing the gas can the weight difference would be equal to the weight of fuel added to the gas tank. The only technical information we needed to know was how much a gallon of gas weighs. This figure could be found in many chemistry books. It did vary slightly from source to source, but a commonly found figure was 6.152 pounds per gallon (16:2194). The best procedure was to determine the specific gravity of your fuel and then calculate your pounds per gallon. Specific gravity of gasoline differed from one location to the next and also from season to season; however, it was in the range of S.G. = .720-.750 at 60°F. To determine the specific gravity of a fuel a hydrometer with the proper range could be used (Appendix C, Figure 5), or the standard chemical method for determination of the specific gravity of a liquid could be used (Appendix C, Figure 6). The overall accuracy of the weight method for determining fuel consumed was better than other methods

available. The only apparatus necessary was a scale in the proper range. Scales which measure to one-tenth of a gram were available for a cost of $50-$100. The major disadvantage of this method was the necessity to handle the fuel and the time it took to refuel after each test run.

For very accurate fuel quantity measurements it was possible to use a chemistry burette (Appendix C, Figure 7). The burette served as a small gas tank. This method worked well for efficiency tests on small engines which were stationary, but because most burettes held only 50 to 100 cubic centimeters of fuel it was not a practical method to use on a passenger car. Even at 50 miles per gallon, the 100 cubic centimeter burette would be emptied in less than two miles. The burette method did, however, have the advantage of accuracy and low cost. Burettes could be purchased for $15 to $30 and were usually calibrated to tenths of a cubic centimeter. This necessitated converting to gallons. One gallon was equal to 3785.4 cubic centimeters (24:33). Another way to look at the figure was to say that one-tenth of a cubic centimeter (smallest graduation on a burette) was equal to 1/37854 of a gallon. This was without doubt the most accurate method of fuel measurement available at a low cost.

The final practical method for fuel measurement, and possibly the most useful for fuel economy research, was the flow meter. This type of meter could be mounted in the vehicle and gave a continual measurement of fuel used. For this reason, it was very easy to make test runs because the car did not have to be refueled at the end of each test. Flow meters came in two basically different forms. The first type sampled the fuel flow by placing a small spinning wheel in the fuel stream. This type was considered to be a non-positive displacement style of meter. One such

meter was the SpaceKom, Model 5100 (Appendix C, Figure 8). This meter was sold by Sears for $50 and had a digital display measuring to the hundredth of a gallon (15:1). The primary disadvantage of the non-positive displacement meter was lack of accuracy. The accuracy was much better than the "fill the tank" method because it eliminated the variable of tank fullness, but these units needed to be calibrated quite often to be sure that one gallon on the meter was one true gallon. This calibration procedure could be done by the individual running the mileage tests but was quite time consuming. A second fuel flow meter was the positive displacement type. In this style, fuel was drawn into a measured chamber until the chamber was full. Then this measured quantity of fuel was completely discharged before the chamber was once again filled. An example of the positive displacement meter was the Kent Moore Model J-22243 "Mile-O-Meter" (Appendix C, Figure 9). This meter measured fuel flow to one-thousandth of a gallon. The majority of testing reported in this thesis was done with this meter. Its accuracy proved to be better than one percent and it was a most serviceable and dependable meter with which to work. The only disadvantage of this meter was its cost, which at the time or purchase (1974) was $180 (20:1). This price was not high for serious research but was slightly out of range for the typical motorist. A number of new flow meters were appearing on the commercial market. The price seemed to be coming down and also new features such as built in mpg calculations were becoming available. It should be noted that most consumer units were of the non-positive displacement type.

In this section, a number of usable methods have been discussed with which fuel quantity can be measured. The general methods included tank filling, fuel weighing, burette measuring, and flow meter readings.

Each of these methods with their variations provided different advantages and disadvantages in such areas as accuracy, portability, and cost. One final method of fuel measurement should be mentioned. This method did not measure the fuel going into the engine, but instead measured the by-products of combustion found in the exhaust gases. This method was highly accurate but well beyond the cost and skill level of most fuel economy researchers. The United States Environmental Protection Agency used this method to determine the fuel economy ratings of all cars sold in the U.S. each year (Appendix C, Figure 10). The city and highway fuel economy values found in the "Gas Mileage Guide" were computed from tests approved by the Environmental Protection Agency. These tests were performed on vehicles by the automotive manufacturers to demonstrate compliance with the requirements of the Clean Air Act and the Energy Policy and Conservation Act. Each vehicle was tested under precisely controlled conditions by professional drivers in a laboratory on a dynamometer (41:7). The 1978 Gas Mileage Guide described the test as follows:

City Test

> This test simulates a 7.5 mile, stop-and-go trip with a speed range of 0 to 56 mph, and an average speed of 20 mph. The trip takes 23 minutes and has 18 stops. Eighteen percent of the trip is spent idling, such as would be expected in the city at traffic lights or in rush-hour traffic. Two kinds of engine starts are used. One is a cold start, which is similar to starting a car in the morning after it has been parked all night. The other is a hot start, which is similar to starting a vehicle after having parked it for a short time while shopping. The information from this test is then combined to represent the fuel economy of that vehicle during a realistic mixture of hot and cold starts during urban driving conditions.

Highway Test

> This test simulates a 10-mile, non-stop trip that begins with the vehicle warmed up. The trip has an average speed of about 50 mph and lasts 13 minutes. The speed during the test ranges from 0 to 60 mph. If your highway driving speed averages faster than the test's average of 50 mph, you should expect to achieve poorer fuel economy than the

highway fuel economy estimate in this Guide--about 10 to 15 percent less for every 10 mph above 50 mph (41:8).

There was much debate over the fuel economy figures determined by the test. There was little doubt, however, that the test procedures and measurement technique produced excellent accuracy of results and control of variables. For the consumer, the test results provided an excellent guide to the relative efficiency of various cars available to the public.

III. Variables Affecting Fuel Economy Test Results

When testing the fuel economy of a car there would ideally be only three factors involved. These factors would include distance traveled, fuel consumed, and the single variable being tested; for example, the fuel economy difference between driving 70 miles per hour versus driving 55 miles per hour. Test results which had only this information would be easy to analyze. Unfortunately, many other forms of variables were present when testing was being done. It was the job of the individual conducting the test to realize what these variables might be, minimize or eliminate them when possible and make note of the remaining variables in the test results to aid in the final analysis and decision making process.

When looking at variables in fuel economy testing, it seemed that they fell into one of four general categories:

Weather - had there been any change in atmosphere conditions

Driver - how accurately had the driver performed his task

Vehicle - had unwanted changes occurred to the car during the test

Course - had the road surface or traffic condition varied

Weather

This variable could be dealt with in several ways. First,

whenever practical, a test was run in a short period of time. This usually assured that atmosphere conditions changed very little. When a test could not be completed in one session, the researcher had to wait until a similar set of weather factors occurred. Secondly, weather readings would be taken at the start and finish of each test. The conditions noted would have included wind, temperature, barometric pressure, relative air density, and relative humidity. A portable set of test instruments can be taken to the test site (Appendix C, Figure 11). Each of these conditions could affect test results. There was no practical way to equate a run made at 35°F with another made at 95°F. All the researcher could do was to discount these test results or try to duplicate the condition in a subsequent test. The ultimate control of these variables could be maintained in a test laboratory which had each of the weather factors regulated. The cost of such a laboratory facility was usually prohibitive and had other drawbacks when compared to actual road testing.

Driver

The driver's responsibility was to eliminate any variation in his technique from one test run to the next. The most important factors to be watched were: speed, rate of acceleration, braking, steering, and shifting points. To minimize driver variation, a pre-determined set of driving instructions should be developed, and during the test, time intervals should be recorded in order to later be able to compute the speed of the test vehicle. Vehicle speed was the single most important variable in this area.

Vehicle

Like the weather, little or no change in vehicle variables

occurred if the test was run in a short time period. Unlike the weather, it was possible to change the vehicle variables prior to the start of any test run. Some of the most important variables in this area included: tire pressure, weight, wheel alignment, and the general tune-up specifications such as timing, spark plugs, and carburetor adjustment. This area was greatly complicated when using more than one test vehicle. Unless the test actually involves the difference between two cars, it was best to run all tests with a single vehicle.

Course

The final set of variables was found in the test course. The best way to eliminate variables in this area was to use the same course all the time. However, even when this was done such items as traffic conditions changed from test to test. It was not advisable to use more than one test course because there was no way to determine the quantative differences from location to location.

IV. Summary

Measuring fuel economy was not just a simple matter of dividing the miles traveled by the gallons used. If fuel economy research was to be accurate and meaningful the researcher must decide the best overall method to measure efficiency for his application before the research was begun. Only then was the data collected relevant to the questions being asked. The method of selection process must include a choice of which fuel economy unit to use, how to measure the distance, how to measure the fuel, and finally how to control and record the variables. Several factors which influenced the decision of method were cost, availability, time, and location.

Chapter 5

FUEL ECONOMY TEST PROCEDURE AND RESULTS

A number of procedures were used to test the fuel economy of passenger vehicles. Each method had advantages and disadvantages related to the economy factor being tested. The test procedure used for this study was selected to give results accurate within the limitations of the test equipment and time duration available.

The factors selected to be tested were chosen to represent some of the conditions the average motorist would be able to control in his driving, maintenance, or car selection decisions. In addition, the factors selected were thought to have a large enough effect to be measured by the test procedure.

I. Test Procedure

Ideally, any test procedure controlled all variables in the test except the single variable being studied. The test procedure developed for this research attempted to do this within the accuracy limitations of the measuring equipment being used in the study. The basic procedure involved consideration of the car, the course, fuel measurement, and the weather. Also, a test for overall repeatability was developed to determine the accuracy limitations of the procedure.

The Cars

A variety of different cars were used in the study. Some were

chosen only because of their availability while others were used because they had the specific options or equipment which the individual test was attempting to evaluate. To eliminate as many unwanted variables as possible, each car was examined prior to the test to determine its basic running condition. This examination involved a check to be sure the major tune-up adjustments were set to the manufacturer's specifications and also included a test drive to be sure the vehicle operated smoothly and had no major driveability problems.

After the preliminary examination of the car, the "Vehicle Description" form (Appendix A) was filled out. This form was used as reference for the test results and the following evaluation. It included such data as make, year, body style, odometer reading, and general engine condition of the car. Also listed on the form was the basic engine information on size and tune-up specifications. The final data recorded was miscellaneous information on axle ratio, transmission type, brake type, tire pressure, vehicle weight, and a list of other power accessories found on the car.

Just prior to the actual test, two specific items were tested on the car. First, as the fuel measuring equipment was being attached to the car, the fuel pump pressure was measured. The fuel flow gauge had to have between three and six pounds per square inch of pressure to operate. Without this pressure the car was either eliminated from the test or was modified to provide the proper pressure. Second, the tire pressure was checked and adjusted to ensure uniformity in the rolling resistance.

It should be noted that no attempt was made to check the accuracy of the car's odometer, speedometer, or fuel gauge. The areas of distance, speed, and fuel consumption were all to be measured by other, more accurate means during the actual tests.

The Course

To control variables, a test course should be of a set length and terrain and be able to be negotiated with consistency by the driver. The length of the course should be long enough to at least give mileage results to tenths of miles per gallon with respect to the accuracy of the fuel measurement procedure. For example, when measuring fuel to the nearest tenth of a gallon, the course should be at least 100 miles long. This was based on a fuel consumption rate of 20 miles per gallon. In the test procedure used in this study, the fuel was measured to the thousandth of a gallon. A one mile long course would have been the minimum acceptable distance, but a ten mile, two direction test was chosen to provide more accurate results. The course was designed to test highway mileage.

The course itself was located on U.S. Highway 169 in Minnesota between the cities of Mankato and St. Peter. The course was located between the mile markers 56 and 61.

Running of the course involved starting out headed north on Highway 169 from Mankato and getting up to the desired speed before reaching the mile 56 marker. The speed was 55 miles per hour for all tests except the test which involved speed as the variable being studied. With the speed stabilized, the fuel flow meter and stopwatch were started just as the car passed the mile 56 marker. After driving steadily for five miles, the stopwatch and fuel flow meter were stopped just as the car passed the mile 61 marker. At this point the car was slowed down and turned around. Then, the desired speed was reached and the stopwatch and fuel flow meter were once again started just as the car passed the mile 61 marker headed south. Finally, the stopwatch and fuel flow meter were stopped at the mile 56 marker. The measurements of time and fuel consumption were then

entered on the "Mileage Test Worksheet" (Appendix A), and the next test run was started.

This mileage test procedure as outlined in Appendix A gave fuel economy over a ten mile distance at a constant speed. The two directions of travel helped minimize the effect of wind. Traffic was usually no problem because the route was a four lane divided highway. If a traffic problem did arise, the run was aborted and restarted from the beginning. Consistent driving proved to be easy as the course required no driver maneuvers other than straight steering and constant speed.

Fuel Measurement

The equipment used for fuel measurement was the Kent Moore Model J-22243 "Mile-O-Meter". This meter was of the positive displacement variety and registered flow in thousandths of gallons. The meter was first calibrated and then installed in each of the test vehicles. Installation involved splicing into the fuel line of the car between the fuel pump and the carburetor.

The meter worked well in all cars except several imported models which did not deliver the needed three to six pounds per square inch pressure from the fuel pump. In these cases, an auxiliary electric fuel pump was added.

Control of Variables

The major driving variable was vehicle speed. Because speed is such a large factor in fuel economy it was measured for each run with the use of an electronic stopwatch. Any run which was more than one-half mile per hour off either way was redone. Traveling 10 miles at 55 miles per hour takes 654.55 seconds. With a tolerance of one-half mile per hour

this gave the drive a time window of plus or minus six seconds.

The total affect of weather conditions could not be determined. It was an accepted fact, however, that a change in conditions affected the fuel economy of a vehicle. Each test was set up to be run in a single test session so it was not necessary to equate results from one day to the next. To be sure there was little change during a given test, the weather conditions were checked before and after each test. Tests typically took about two hours to complete. During this time temperature change was limited to a maximum of ten degrees Fahrenheit, wind change limited to five miles per hour and barometric pressure change limited to five hundredths of an inch of Mercury. Any test session which exceeded these limits was redone at a later date. Equipment for measuring these conditions was set up at the test site.

Traffic conditions were yet another variable. However, most of the testing was done early in the morning and traffic on the test course was minimal. If any condition which caused a speed variation, a lane change or a change in wind existed during a given test run, that run was aborted and then restarted.

The final variable was human or equipment malfunction. Such items as forgetting to start or stop the watch or flow meter caused that test run to be redone.

Test Sequence

The test sequence began by determining the factor to be tested and then finding an appropriate vehicle. Next, the vehicle was given a general inspection for state of tune and test run for driveability. "The Vehicle Description Form" was filled out, the fuel flow meter attached, and final tire pressure set just prior to the start of the test.

With the preliminaries completed, the test session began by measuring and recording the temperature, barometric pressure, humidity, and wind velocity and direction. The first test run was in the base condition. With that run completed, run number two was made with the condition changed. The third run was the same as the second, no changes were made. Then the vehicle was returned to the base condition for the fourth and final run. All time and fuel consumption data was entered on the "Mileage Test Worksheet" (Appendix A). The weather conditions were again measured and recorded. The test run was concluded and calculation of test results could be completed. Finally appropriate conclusions were drawn.

Test Result Calculation and Summary

Weather data was first checked to determine if the test was conducted within established limits. If it was, the actual fuel mileage was calculated for each test run and entered on the "Calculations and Results" form (Appendix A). Mileage was listed in miles per gallon and all comparisons listed the change as a positive or negative percentage of the base mileage. For example, if the test measured the factor of tire pressure with the base pressure being 20 pounds per square inch and the changed condition being 40 pounds per square inch, the results showed a change from 20.51 miles per gallon to 21.82 miles per gallon. This was listed as a +6.4 percent change.

With the test results calculated, the final step was to summarize the test on the "Mileage Test Summary" form (Appendix A). This form called for the researcher to list the purpose, procedure, and results of the test and also draw final conclusions on the effect on fuel economy of the factor being tested.

II. Test Results

The following results were obtained using the test procedure described in the first part of this chapter. All results are related to highway driving. No attempt was made to simulate mixed traffic conditions. The results of the testing were summarized in this chapter. The actual data, description and calculation sheets were included in Appendix A.

Error Determination - Test #1

Car: 1974 Chevrolet Nova, 6 cylinder, automatic

Test Description: No changes were made to the car or to the driving procedure. This was done to establish the degree of repeatability of the test results.

Test Results: Mileage varied by a maximum of .6 percent during the test while speed varied by a maximum of .8 percent.

Test Conclusions: Based on this test it was decided to use a one percent change as the level of significance for future tests.

Air Cleaner Reversal - Test #2

Car: 1974 Chevrolet Nova, 6 cylinder, automatic

Test Description: With the air cleaner top put on upside down, cool air was allowed to enter the carburetor. This had the effect of providing a leaner mixture to the engine.

Test Results: Mileage was two percent better with the air cleaner top put on upside down, than it was with it in the normal position.

Test Conclusions: While a small gain was found, it was concluded that a possible fire hazard existed when this tactic was employed and another method of achieving the same results was to reduce the fuel flow by changing main jet sizes to lean the air mixture.

Vehicle Speed - Test #3

Car: 1974 Chevrolet Nova, 6 cylinder, automatic

Test Description: The car was driven at speeds of 45 miles per hour, 55 miles per hour, and 65 miles per hour to determine the effect of driving at speeds both higher and lower than the legal speed limit of 55 miles per hour.

Test Results: Drastic change was found in this test. Using 55 miles per hour as the base speed, a 10.5 percent loss in fuel economy was found as the speed was increased to 65 miles per hour. However, when the speed was lowered to 45 miles per hour, a gain of 11.1 percent was found.

Test Conclusions: While there was no question that speed affects fuel economy, the degree of the effect was more drastic than expected. Dropping the speed limit to 45 miles per hour would have a large effect on fuel consumption. In times of short fuel supply and high fuel costs, lower vehicle speed would be an immediate method to conserve fuel.

Power Steering - Test #4

Car: 1974 Chevrolet Nova, 6 cylinder, automatic

Test Description: Power steering was used on many larger cars to assist the driver in turning the steering wheel. This required power which the car's engine provided. This test was conducted to measure the effect power steering had on a car's fuel economy while being driving in highway type driving.

Test Results: The difference found while running the car without its power steering was a gain but the gain was less than the one percent error factor which had been determined for the test procedure. Thus, the test showed no significant loss of mileage due to power steering.

Test Conclusions: Power steering was not a negative factor with regard to fuel economy in highway driving. Different results may exist in city or mixed flow driving which require a large number of turning maneuvers.

Window Position - Test #5

Car: 1974 Chevrolet Nova, 6 cylinder, automatic

Test Description: This test measured the fuel economy difference between driving with the windows rolled up and driving with them rolled down. Driving with the windows rolled up made the car slip through the air with less friction. This required less horsepower output from the engine.

Test Results: A 1.5 percent gain was found with the windows rolled up.

Test Conclusion: Driving with the windows up does save fuel. However, on warm days this might mean turning on the air conditioner, lowering the car's fuel economy. The loss of economy from using the air conditioner was partially offset by having the windows rolled up. Another factor to consider in vehicle design was the use of fresh outside air in a flow through ventilation system which allowed the windows to remain up. Driver fatigue and interior noise level were also lessened when the windows were rolled up.

Tire Pressure - Test #6

Car: 1974 Chevrolet Nova, 6 cylinder, automatic

Test Description: This test was conducted to determine the fuel economy effect of under or overinflated tires.

Test Results: An increase of 10 pounds per square inch over the

recommended pressure produced a 1.6 percent gain in fuel economy while a 10 pound per square inch lowering of the pressure produced a loss of 4.8 percent.

Test Conclusions: There was little fuel economy to be gained by overinflation of tires. Any gain was lost by increased tire wear in the center of the tread surface which would cause more frequent replacement of the tires. The loss in mileage with underinflated tires was fairly large. This condition also causes excessive tire wear and produces extra heat from friction which can damage the tire. Both overinflated and underinflated tires caused a loss of vehicle handling potential and were considered a possible safety problem. For best all around performance, tire pressure should be kept near the recommendation of the manufacturer.

Air Conditioning - Test #7

Car: 1973 Chevrolet Monte Carlo, 8 cylinder, automatic

Test Description: The car was tested with and without the air conditioner running to determine the affect of the air conditioner on fuel economy.

Test Results: Using the air conditioner caused a 4.3 percent drop in fuel economy when driving at highway speeds.

Test Conclusions: This loss was even greater when the car was operated at lower speeds or in mixed flow traffic. In addition, a vehicle weighed over 100 extra pounds when equipped with an air conditioner and this reduced fuel economy even when the air conditioner was not in use.

Extra Weight - Test #8

Car: 1976 Fiat X 1/9, 4 cylinder, 4 speed

Test Description: An extra 600 pounds of weight was added to the

car to determine the mileage effect of weight at highway speeds.

Test Results: There was a two percent loss of fuel economy.

Test Conclusions: Weight was not a critical mileage factor at steady speeds. However, it was expected that the affect of the additional weight would show up much more in stop-and-go driving cycles or in hilly terrain.

Tire Size - Test #9

Car: 1974 Fiat X 1/9, 4 cylinder, 4 speed

Test Description: Tires with a larger diameter were tested to see if the increased size would affect the car's fuel economy.

Test Results: With tires which were one-third larger in diameter, a gain of 17.5 percent in fuel economy was observed.

Test Conclusions: Larger tires reduced the speed which the engine must run in order to maintain a given road speed. In this test at 55 miles per hour the larger tires reduced the engine speed by almost 1,000 revolutions per minute. With the engine running slower, better fuel economy was available. In new vehicle design a more acceptable way to achieve the same result was to change to a higher final gear ratio. One drawback of large tires or higher gear ratios was poorer rates of acceleration.

Overdrive - Test #10

Car: 1977 Dodge Van, 6 cylinder, 4 speed overdrive

Test Description: Overdrive, like larger tires allowed the engine to revolve more slowly at a given vehicle speed. This test measured the mileage change while driving in an overdrive gear.

Test Results: Using an overdrive of slightly over one-third, fuel

economy improved by 19.1 percent.

Test Conclusions: Overdrive had an effect which was similar to the larger tires. The engine ran more slowly and the fuel economy improved. The advantage of the overdrive was that the vehicle maintained the normal levels of power and acceleration when the standard gears were used. Overdrive was only employed when the vehicle was maintaining a steady speed and acceleration was not required. One disadvantage was that overdrive was not currently available on cars with automatic transmissions.

III. Summary

While there were any number of acceptable and usable test procedures available which were used to measure fuel economy, it was important that a method was chosen which yielded accurate results for the economy factors being tested.

The method employed for this study used a relatively short test course but accurate fuel and distance measuring techniques. The result was a test procedure which was accurate within one percent for a given test.

The factors tested included a sample of different ideas on fuel economy improvement but did not attempt to cover all possible areas. Much interesting work remained to be done in this area.

Chapter 6

A REVIEW OF MANKATO STATE UNIVERSITY ECONOMY PROJECTS

The fuel economy of various automobiles has always been a topic of conversation. It is one of the basic measures of a vehicle's performance. However, since the end of World War II it had not been a major national concern until the fall of 1973. The United States had voiced support for Israel during the 1973 October War, and as a reprisal for this action, the Arab oil producing nations adopted, on October 20, 1973, an oil embargo against the United States and several other countries (31:1). Then in early November, President Nixon took action in several areas including asking for the banning of gasoline sales on Sundays, and a nationwide 50 mile per hour speed limit (13:24). Both of these measures required legislation, and on January 2, 1974, the National Emergency Highway Energy Conservation Act was signed into law (39:6). The law prohibited the U.S. Secretary of Transportation from approving Federal-aid highway projects in any state having a maximum speed limit in excess of 55 miles per hour. Within two months, all 50 states were in compliance with the law. The specific law in Minnesota (Highway Speed Reduction, H.F. No. 2862) did not actually set the speed limit, but it gave the executive department of government the authority to impose highway vehicular speed restrictions upon a finding by the governor that such speed restrictions were necessary to conserve fuel (27:11). The law was passed on March 1, 1974. Governor Anderson made his decision on March 2, 1974, and

the speed limit became effective at 12:01 a.m., March 3, 1975, making the State of Minnesota one of the last states to comply (26:1).

During the same time period, the public was also becoming aware of the fuel shortage in other ways. In some locations, gasoline was not available and in all locations the price was going up. Christmas of 1973 saw the majority of Americans, for the first time, paying more than 50 cents per gallon for their gasoline (32:611). The combined factors of lower speed limits, higher cost, and less availability were enough to convince the majority of Americans that there was, indeed, a shortage and something had to be done.

I. The 50/50 Experimental Economy Vehicle (EEV)

The Beginning

Students at Mankato State University were no exception to the national consensus. In particular, the students enrolled in a new Industrial Technical Studies Department course offering entitled "Gasoline Engine Technology" expressed an interest in studying the topic of automotive fuel economy. The course began winter quarter, 1974 and the decision was made to attempt to transform textbook theory on fuel economy into practical application. The idea of the project vehicle was born.

The Goal

The general goal of the project was to modify a vehicle in an attempt to improve its fuel economy. The project began at a time when President Nixon was proposing a 50 mile per hour speed limit and the price of gasoline was 50 cents per gallon. The specific goal was to be able to obtain a fuel economy of 50 miles per gallon with a car capable of driving

50 miles per hour on the highway in normal traffic. From this goal was chosen the project vehicle name of "50/50 EEV": The 50/50 not only indicated the goal but also suggested a compromise between speed and economy. The final part of the goal was to have the vehicle completed in time for the annual Industrial Arts Conference at Mankato State, which was scheduled for May 2. 1974.

The Vehicle and Modifications

As the project started, the search began for a suitable test vehicle. The school's previous experience with Volkswagens, and the fact that they were lightweight and had better than average fuel economy to begin with, weighed heavily in the selection process. Dr. George V. Komaridis, of Mankato State University, agreed to donate a 1966 Volkswagen body and miscellaneous parts to the project. The car had over 120,000 miles of previous service and showed each and every mile (Appendix C, Figure 12). In addition to the car provided by Dr. Komaridis, a variety of other used mechanical parts were collected from local dealerships, junkyards, and individuals. Virtually every part that was to go into the car was used or salvaged.

Work began with different students taking responsibility for various portions of the project. Body work, engine work, and interior work all went on at the same time. The cosmetic body and interior work was done mainly to improve the appearance of the car. It involved repairing damaged body panels, removing rusted sections, repainting the body, and cleaning the interior. The car had been hit from the rear and the fenders and engine cover were bent totally out of shape. The decision was made to remove this section of the car to save the cost of new fenders and also to expose the engine for easy working access and display purposes.

While the cosmetic body and interior work progressed, the engine was being rebuilt and modified for maximum fuel economy. The major idea was to reduce the performance level in order to obtain more efficiency. This concept was put into practice by using only one-half of the original engine. This left the engine with only two cylinders, a 596 centimeter displacement (about 36 cubic inches) and a power rating of approximately 20-25 horsepower (Appendix C, Figure 13).

In addition to the two cylinder modification, the following engine changes were also made:

	MECHANICAL
BALANCE	Pistons and rods balanced to a tolerance of ¼ gram
CYLINDER ARRANGEMENT	Pistons and rods for #1 and #3 cylinders removed
PISTONS	Machined to a dome shape top, weight removed from skirt area
CONNECTING RODS	Lightened by removal of cap material and drilling holes in web
CRANKSHAFT	Oil holes blocked on #1 and #3 journals
CYLINDER HEADS	Flycut to raise compression ration and intake valves undercut to improve low lift air flow
	IGNITION
DISTRIBUTOR	Advance curve modified to operate at lower vacuum and two lobes removed from distributor cam
DISTRIBUTOR CAP	Two secondary terminals removed and filled
	FUEL
CARBURETOR-FUEL PUMP	Re-jetted to obtain proper air/fuel ratio. Pressure reduced to 1.5 PSI for low speed operation
AIR INTAKE	Heated by the exhaust system
	LUBRICATION AND COOLING
OIL PASSAGES	Lifter bores plugged for #1 and #3 cylinders

ENGINE COLOR	Changed from silver to black to increase heat dissipation ability

EXHAUST

HEADERS	Designed for low speed operation

Along with the engine work the chassis and body also received some technical attention. The car had a wheel base of 94.5 inches and was rear engine, rear wheel drive. Some of the modifications included:

CHASSIS

TIRES	Radial ply, large diameter on rear to reduce gear ratio and small diameter on front to reduce air drag
BEARINGS	Light weight lubricant to reduce friction

BODY

WEIGHT	Reduced by removal of rear section - total vehicle weight = 1,580 pounds
AERODYNAMICS	Front air dam installed to reduce under vehicle turbulance, rear spoiler added to smooth air flow over rear of car

The final work on the car involved the installation of the engine and the final detailing of the body. Dr. Robert I. Johnson and several of his students put their design expertise to good work in developing the door design and logo for the project (Appendix C, Figure 14). The last bolt was tightened and the car was ready for its first trial run on April 26, 1974 (Appendix C, Figure 15).

The Tests

Late in the afternoon of April 26, the "50/50 EEV" began its first test run. A 1.122 mile long course had been set up on city streets around the upper campus area of Mankato State University. The fuel was being measured with a 100 cubic centimeter burette which was mounted on the car. The students had determined that the car must go around the course on less

than 85 cubic centimeters of gas to have a mileage of over 50 miles per gallon. The first trip around the course showed only a 37 mile per gallon average but by the fifth attempt, the 50 mile per gallon barrier had been broken with a run netting 50.085 MPG (33:44). At the completion of that run the "50/50" was put back in the Auto Technology Laboratory and prepared for the annual Industrial Arts Conference to be held the next Thursday. During that conference the car was test driven by a number of individuals and many of them were able to exceed the 50 mile per gallon goal. In addition to the mileage testing, the "50/50" also had its emission levels tested at the conference. The results showed .5 percent CO and 170 ppm HC. While it could not be estimated how well the car would do if subjected to the Federal Emission Test Procedure, the engine did register clean enough to pass current standards for any state.

The initial test was quite limited in both distance and speed, so a longer test course was set up on roads between Mankato and St. Peter, Minnesota. The round trip distance of the course was 27.94 miles, consisting of 26 percent city, 33 percent rural, and 41 percent freeway driving. This test was devised to determine if the car could operate in mixed traffic, go at least 50 miles per hour on the highway, and obtain a fuel economy of 50 miles per gallon on a normal short trip consisting of various forms of driving. On May 17, 1974, the "50/50" completed the test with highway speeds near 53 miles per hour and an overall fuel economy of 51.3 miles per gallon (33:44).

By the end of May the "50/50" had been on numerous short trips and test runs but had not yet attempted a long trip. The decision was made to drive the car to Chicago. On June 1, 1977, at 10:00 a.m. two Mankato State University students left Mankato. Ten hours, 415 miles and

7.988 gallons of gas later, the car arrived in Chicago averaging 51.95 miles per gallon (28:3). While on the freeway, the car was kept between 50 and 55 miles per hour.

On June 28, 1974, as a result of their research, the students at Mankato State University were awarded the "Blue Flame Ecology Salute" by the Blue Flame Gas Association for their contribution in the areas of economy and emissions (21:5).

During the next school year, work continued on the "50/50" at a somewhat slowed pace until the Industrial Technical Studies Department decided to display the vehicle at the 1975 American Industrial Arts Association National Convention held at Cincinnati, Ohio. The week long convention began on March 24, 1975. With the weather still cold and with snow still on the ground some thought was given to taking the car on a trailer rather than driving. Rather than pass up a chance for another long distance mileage run, the car made a test run out of the 776 mile trip and averaged a new high of 54.7 miles per gallon. At the convention the students talked to faculty members of Western Washington State College and found out about an inter-collegiate mileage rally planned for August, 1975. Enthusiasm for continued mileage research grew.

Co-sponsored by the University of California at Los Angeles and Western Washington State College, the Student Engineered Economy Design (SEED) Rally was conceived as a vehicle design competition with the objective to encourage creative effort by educational and industrial concerns and to demonstrate new ideas for practical transportation alternatives. Events of the Rally started with a performance test to determine the structural stability and mechanical reliability of each vehicle. Next was a 1400 mile economy run from Bellingham, Washington to Los Angeles,

California. The final event consisted of emission testing using the U.S. Environmental Protection Agency's certification test. The event was held from August 23 through August 29. The "50/50 EEV" entered by Mankato State did very well in the competition by placing first in fuel economy and second in performance. However, tenth place in emission leves kept the entry out of first place overall. That honor went to Western Washington State College. Mankato State earned second place overall in the educational division. The mileage obtained by the "50/50" for the 1400 mile trip was an official 61.98 miles per gallon (43:6). The success of the "50/50" drew much favorable attention to Mankato State including the CBS Evening News (10), newspaper articles including a feature article in the Minneapolis Star (25:1C), and a magazine article in a publication called VW Greats (35:26-28).

After the SEED rally, the "50/50" was displayed at many public showings and also appeared at a number of automobile shows where it competed for awards in design excellence. In addition, many oral presentations were given by the faculty and students involved with the project. It should also be pointed out that Mankato State, through Faculty Research Grants and some travel money, provided funds for the completion of the project and its competition in the SEED Rally.

II. The Spirit of 76 MPG

The Beginning

During December of 1975, it was announced that there would be a cross-country mileage rally held the next summer. The rally was to run from Bellingham, Washington to Washington, D.C., a distance of over 3,000 miles and was called the "Sea to Sea Econorally". This announcement

once again stirred the interest of students at Mankato State.

Fiat Motors of North America, Inc., was contacted during January of 1976 to determine if they would be interested in participating in the project and rally. After an affirmative response, a formal request was made to Fiat. The proposal asked for Fiat to donate a vehicle to Mankato State University for use in the economy research. In addition, some parts and technical assistance were also to be provided. In return, Mankato State would make all research results and information available to Fiat for their technical and publicity use. The proposal was accepted by Fiat and on May 30, 1976, five students and their faculty advisor left Mankato for Long Beach, California to pick up one new 1976 Fiat X 1/9 sports car and a second similar car, which had been damaged, to be used for spare parts (Appendix C, Figure 16). Ninety hours and some 4,000 miles later, the new project car arrived in Mankato and was placed in the Automotive Technology Laboratory where work was begun on transforming it into a high mileage - low emission test vehicle.

The Goal

As had been done on the previous project car, a set of goals were established at the start of the new project. The general goal was to improve the fuel economy and in addition to maintain the already excellent exhaust emission levels of the car. Emission levels had not been the original goal of the "50/50 EEV" project. With the "Sea to Sea Econorally" in mind, the specific goals became: (1) to win the rally; (2) to pass the federal emission test; and (3) to achieve a mileage of 76 miles per gallon. From this final goal came the project title of the "Spirit of 76 MPG" (Appendix C, Figure 17).

The Vehicle and Modifications

The two prime considerations for fuel economy on the project were to reduce the weight and also reduce the performance level of the car. The "Sea to Sea Econorally" rules contained two weight classifications which were lightweight (up to 2,000 pounds) and heavyweight (over 2,000 pounds). The weight of the X 1/9 started out at 2,050 pounds. From this weight the decision was made to enter the heavyweight class. This allowed a concentrated effort to be applied to the engine modification. Also entering into this decision was the possibility that Mankato State would enter a second vehicle in the rally. Plans were underway to put the "50/50 EEV" motor into a lightweight fiberglas body, thus giving Mankato State an entry in each of the weight classes for the "Sea to Sea Econorally".

The second consideration was performance level, and once again, as with the "50/50", the engine was reduced in size by using only half of the cylinders. The two cylinder, single overhead camshaft, water cooled engine had a total displacement of 654 cubic centimeters (39 cubic inches). Its estimated power output was 30 horsepower at 6,000 revolutions per minute. In addition to the two cylinder modification, the following engine changes were also made:

MECHANICAL

BALANCE	Crankshaft counterweights removed, pistons and rods balanced to a tolerance of ¼ gram
CYLINDER ARRANGEMENT	Pistons and rods from #1 to #4 cylinders removed
CYLINDER HEAD	Milled .058" to bring compression ratio from 8.5 : 1 up to 10.5 : 1

IGNITION

DISTRIBUTOR	Advance curve modified to operate at lower vacuum Partly shorted to provide voltage to two cylinders

FUEL

CARBURETOR	Re-jetted to obtain proper air/fuel ratio, adapted to include water vapor injection, fuel heated before entering carburetor, secondary blocked off
AIR INTAKE	Air heated by exhaust system

LUBRICATION AND COOLING

OIL	Synthetic oil used to reduce engine friction 5 W-20 Mobil #1
RADIATOR	Could be blocked-off with moveable cover to enable driver to keep engine temperature up to maximum (200-220°F)

EMISSIONS

AIR PUMP	Modified to feed two cylinders
EGR VALVE	Re-jetted to feed a smaller amount of exhaust for recirculation
CATALYST	New converter installed to maximize performance of chemicals

INSTRUMENTATION

GAUGES	Fuel flow meter - Voltmeter Cylinder head temperature Exhaust gas temperature - Vacuum gauge

Along with the engine work, the chassis and body also received attention. The car featured a transversely mounted engine located in the mid-engine position and a wheelbase of 86.7 inches. Some of the modifications included:

CHASSIS

GEAR RATIO	Final drive ratio raised to provide less engine revolutions per mile traveled
TIRES	Rear tire diameter increased to lower rolling friction and help gear ratio
BEARINGS	Lightweight lubricant used to reduce friction

BODY

WEIGHT	Reduced 50 pounds by removal of spare tire -- total weight 2,001 pounds

AERODYNAMICS Some trim removed to clean-up air flow. Front air dam to reduce under car turbulence. Wing to provide either lift or down force

The completion of the car involved paint and lettering. The car was completed in only six weeks (Appendix C, Figure 18). Much had been done in a short period of time, but only two weeks remained before the start of the rally. Those two weeks were spent making test runs and final adjustments.

The Tests

In the short time period available before the start of the rally, a variety of test runs were made using the Mankato to St. Peter 28 mile test course. Mileage started out in the 40 mile per gallon range and was gradually increased to 48 miles per gallon. The results did not look good at this point but time had run out and it was time to leave for Bellingham and the start of the rally. Final testing was actually completed on the 1,800 mile trip from Mankato to Bellingham, and it appeared that the 76 miles per gallon goal would not be reached but that the car should be in the 50-60 mile per gallon range.

The "Sea to Sea Econorally" began on July 31, 1976, with performance testing. The Mankato State entry did poorly in this test due to its small engine size. However, it appeared that the mileage and emission levels of the Fiat would be more than enough to offset this slow start. Mileage testing began as each of the teams in the rally left Bellingham and headed east. Along the route, overnight stops were made at a number of colleges including Mankato State. As the cars arrived in Detroit, the mileage test was stopped for one day while emission testing was done by Chrysler Corporation's Research Engineering Division. The Fiat passed the 1976 Federal EPA emission test with flying colors. During the emission

test, the EPA mileage was also tested. Even though it did not count in the rally scoring, Mankato State was proud of the 61 Highway - 38 city - 48 combined mileage figures. The rally resumed with the trip from Detroit to Washington, D.C. counting for the remainder of the fuel economy test. After the mileage figures were calculated for the 3,200 mile trip, it was announced that Mankato State not only had won the heavyweight mileage title with 56 miles per gallon (second place was 44.8 miles per gallon), but they had also won the overall heavyweight title. It was also notable that the winner in the lightweight class did only slightly better on mileage with a final 59.1 mile per gallon figure to its credit (34:5).

With the victory fresh in their minds, the group from Mankato State University left Washington, D.C. on August 10, 1977, after a display of rally vehicles on the lawn of the Smithsonian Institute and drove to Fiat's National Headquarters in Montvale, New Jersey, where they spent a day showing off their project car and looking over Fiat's new facility. Upon arrival back in Mankato, fall quarter was about to begin. During that quarter, and later into the 1976-77 school year, the car was displayed a number of times and the question of "What will be done for the next project?" started to be asked.

III. The Bradley GT

While work was being done on the Fiat project car during the summer of 1976, it was decided to go ahead with the idea of a lightweight entry for the "Sea to Sea Econorally". A graduate student and teacher at Hastings High School in Minnesota, James Krause, was at Mankato State University taking course work on his Masters degree. Mr. Krause, along with several other students, took a Bradley GT fiberglas body and fitted

it to a Vokswagen chassis. Then a two-cylinder engine, similar to the original "50/50" was installed. The result was a 1,300 pound economy car (Appendix C, Figure 19). The Bradley GT was entered by Mankato State in the "Sea to Sea Econorally". No emission work had been done on the car but it still did well in the rally. The official mileage in the rally tied Western Washington's entry with 59.1 miles per gallon (14:11), but even greater potential was shown during the EPA mileage test where the car recorded a record 83 Highway - 48 City - 63 combined mileage rating (34:4). The overall finish position for the car was second place in the lightweight class.

IV. The Lancia Beta Coupe

At the completion of the "Sea to Sea Econorally", there was no intercollegiate fuel economy contests scheduled for the next year. Mankato State, however, did want to stay involved with vehicle research; but instead of fuel economy research, a decision was made to enter the performance area. Students at Mankato State formed a Vehicle Performance Team during the spring of 1977 and started looking for a new project.

The Sports Car Club of America has a National SOLO II competition program where cars are timed on an obstacle type course to determine driver skill and car handling. The Vehicle Performance Team approached Fiat and was given use of a new 1976 Lancia to conduct handling research and also to enter in the SOLO II competition (Appendix C, Figure 20). During the summer of 1977, all members of the team had a chance to try their driving skills in local competition. At the end of the summer, the team advisor set up a course and a run-off was held to determine which two drivers would go to the Divisional Championship, held at the Michigan

International Speedway on September 3-4, 1977. Also during the summer, several students tested the handling characteristics of the car on a skid-pad. The skid-pad was a round circle where a car was run up to maximum traction and timed with an electronic timer. From this information lateral acceleration (traction) was calculated.

The team did not do very well at the divisional event, but did well enough to qualify for the National Championship held in Dallas, Texas on October 1-2, 1977 (23:8). At this event, in a field of 27 cars, the two entries from Mankato State finished thirteenth and fourteenth (22:9).

While not being fuel economy research, this new area made use of many of the same techniques that the team had dealt with in the mileage contests from previous years.

V. Future Vehicle Research

During the spring of 1978, Mankato State University was notified of the Energy Efficiency Vehicle (EEV) Competition for 1978-1979. The EEV Competition was an inter-university educational program in which students, under the supervision of faculty, designed, built, and tested innovative prototype vehicles.

Upon notification of the program the Vehicle Performance Team decided to enter the competition. This involved developing a design proposal to be submitted to the organizers of the event. This design proposal was evaluated and the project was funded.

At the time this study was completed, the project car was under construction. The main goals of the vehicle were fuel economy, emissions, and safety.

The fuel economy design centered around four basic concepts.

Vehicle weight was planned to be lowered through the use of aluminum and fiberglas. The design also called for reduced rolling resistance, low aerodynamic drag, and a multiple displacement engine to match vehicle load requirements.

Pollution was to be controlled through the use of propane fuel and a catalytic converter.

The safety design included an integral roll case, seat belts, air bags, collision bumpers, periscopic mirrors, collapsible steering, and an on-board fire extinguisher system.

The EEV Competition was scheduled to be held in Detroit during August of 1979.

Chapter 7

GOVERNMENTAL REGULATION OF FUEL ECONOMY

Since the early days of the motor vehicle, various laws have been enacted and enforced which have regulated almost every aspect of the automotive industry. For example, England's Red Flag Law of 1865 limited the speed of road vehicles to three miles per hour and also required that each vehicle be preceded by a man carrying a red flag (42:13). The law came about due to pressure on Parliament from England's railroad and stage coach industries who were afraid the motorized road vehicle would put them out of business.

By 1972, automobiles in the United States were regulated by the Federal Government in the areas of safety, damageability, noise, and emission controls (8:70).

Fuel economy of automobiles became a topic of national concern in late 1973, with the Arab oil embargo. The Federal government took this as a signal to begin legislation which would regulate the gasoline mileage of passenger cars and light trucks. The first action, and most subsequent actions in this area, were tied to major energy legislation which has covered many additional aspects of the energy problem. For this reason, fuel economy standards have taken a long time to be established and have often been associated with controversial laws or acts at the national level.

I. Legislative History

In 1975, the 94th Congress of the United States in their first session spent a considerable amount of time and effort on a variety of energy-related bills. By December 17, 1975, the Congress had cleared an omnibus energy bill for the White House, and five days later, President Ford announced his decision to sign S622 (PL 94-163), the Energy Policy and Conservation Act (9:70).

The act which President Ford signed was actually a combination and compromise of five acts which had been approved by either the House or the Senate but had never passed both.

The Senate had passed four separate acts, each related to a specific area of the energy crisis. The Stand by Energy Authorities Act, S622, was approved by the Senate on April 10, 1975, and basically dealt with expanded power for the President in energy policy matters. On July 8 and July 11, 1975, two more fragments of the Senate's energy plan, The Strategic Energy Reserves Act, S67, and the Energy Labeling and Disclosure Act, S349, were approved. Finally, the Automobile Fuel Economy Act of 1975 was approved by the Senate on July 15, 1975. These four bills made up the energy package from the Senate but the House was working on its own legislation in this area and did not consider the Senate's versions (11:220).

The House was developing a single energy act which included the area of taxation. All taxation legislation must start in the House. After two months of intermittent debate, the House passed the Energy Conservation and Oil Policy Act of 1975, HR 7014, on September 23, 1975, by a vote of 255 to 148 (11:220).

With the Senate and House each having different versions of energy legislation, a conference committee was organized to produce a single bill,

a process which lasted several months and became a complicated entanglement of compromise, and finally settled on the Senate's original Standby Energy Authorities Act, S622, now called the Energy Policy and Conservation Act.

After all final changes were made, the House approved the measure on December 15, 1976, on House Vote #584, by a 236 to 160 margin and sent it on to the Senate for final Congressional approval. The Senate acted on December 17, 1975, and approved legislation on Senate Vote #595, by a 58 to 40 margin. It should be noted that party lines were followed, with the Democrats voting almost four to one in favor of the legislation while the Republicans voted against it by a three to one margin (11:5).

The strength of the vote did not indicate enough power to override a Presidential Veto if one should occur. President Ford, a Republican, was under pressure to support the Republican segment of Congress by using his veto power but it was not known what his action would be. However, there was also much pressure to have some form of official energy policy. President Ford signed the legislation and S622 (PL94-163), the Energy Policy and Conservation Act became law.

Since this legislation was passed, several unsuccessful attempts to produce new regulations on fuel economy of automobiles have been made. Two basic positions existed on this question. Senator Howard Metzenbaum, a Democrat from Ohio, sponsored several versions of a bill which would place an outright ban on any automobile which did not achieve a specified mileage (5:1). In contrast, the House produced preliminary legislation which would place a punitive tax on any car not meeting the standards. This tax has been referred to as the "Gas Guzzler Tax" (4:1). The tax, in the proposed House legislation, would range from $200 for a 1979 automobile

which could only obtain 15 miles per gallon, up to $3,850 for a 1985 model getting less than 12.5 miles per gallon. The tax would be displayed on the window sticker of the car but would not be deductible on the Federal income tax (38:1).

While neither the banning of cars with poor mileage nor the taxation of such vehicles became law, it appeared that one of these two methods would be employed in future legislation.

II. The Law

The Energy Policy and Conversation Act was made up of five separate titles. Title I dealt with domestic energy supplies and encouraged the increased use of coal and also attempted to ensure domestic energy supplies with a number of specific measures. Title II contained a number of provisions, one in particular equipped the President with standby authority to deal with future energy supply emergencies. Title III contained the automotive fuel efficiency standards along with a product efficiency section on major consumer items such as refrigerators and water heaters. An energy conversation program was also authorized. Title IV dealt with oil pricing and amended the Emergency Petroleum Allocation Act of 1974 with several new provisions. Title V was made up of a number of general provisions which were to provide data upon which future energy policy decisions could be made (11:222-224).

Automotive Regulations: Title III (PL94-163)

Title III contained five sections which pertained to the automotive industry.

First, it required that the average fuel economy for cars

manufactured or imported by any one manufacturer in any model year after 1977 be no less than:

18 miles per gallon in 1978

19 miles per gallon in 1979

20 miles per gallon in 1980

27.5 miles per gallon in 1985 and succeeding years

Second, it directed the Secretary of Transportation to set standards for the interim, 1981-1984, at the maximum feasible average fuel economy level which would result in progress toward the 1985 standard which the Secretary could adjust downward to 26 miles per gallon if necessary. Also, the Secretary would set standards for vehicles other than passenger automobiles at maximum.

Third, it authorized the Secretary to adjust the average fuel economy downward as it applied to a certain manufacturer if he found that other federal standards - such as clean air requirements - reduced the fuel economy of the cars produced by that manufacturer despite the application of a reasonably selected technology to prevent such a fuel economy reduction; and also authorized a smaller downward adjustment in the case of the manufacturer who did not apply such technology.

Fourth, it required labeling of cars manufactured or imported in any year after model year 1976 to indicate fuel economy performance.

Fifth, it set penalties at five dollars per 0.1 miles per gallon for every 0.1 mile by which a manufacturer's average failed to meet the standard, multiplied by the number of cars produced by that company. It also gave a credit in the same amount to any manufacturer for any year in which his average fuel economy exceeded the standard, allowing that credit to be applied forward a year or backward a year against any penalty

assessed him for failure to meet the standard (38:41163).

Automotive Regulations:
United States Code

When a law was passed by Congress and signed by the President, it was then entered into the United States Code. Title 15 of the United States Code was called Commerce and Trade. In this title there are many sections which contain various automotive regulations. The mileage laws from PL94-163 were found in the United States Code; Title 15, Commerce and Trade; Chapter 46, Motor Vehicle Information and Cost Savings; Subchapter V, Improving Automotive Efficiency; Sections 2001-2012.

The law, as contained in the code, was very specific. It was a continuing document which was updated as it was affected by the new legislation or regulations authorized by legislation. Several of the technical specifications in the code related to fuel economy included:

> A passenger car is any 4-wheeled vehicle, propelled by a fuel, which is manufactured primarily for use on public roads and which is rated at 6,000 pounds gross vehicle weight or less or is rated at 6,000 pounds to 10,000 pounds gross vehicle weight and for which the Secretary determines, by rule, average fuel economy standards under this part are feasible (37:43).
>
> Corporate Average Fuel Economy (CAFE) shall be calculated by the EPA administrator by dividing the total number of passenger automobiles in a given model year by a manufacturer by the sum of terms, each term of which is a fraction created by dividing the number of passenger automobiles of a given model type by the fuel economy measured for such a model type (37:48).
>
> Mileage testing shall be done in accordance with EPA emission test procedure. The combined mileage figure made up of 45 percent highway and 55 percent city driving shall be used in the calculation of the CAFE (37:49).

The Code went on to specify the mileage requirements as found in the law, and then was updated as the Secretary of Transportation determined further economy standards as he was charged to do under the law.

Automotive Regulations:
Secretary of Transportation

As found in the law and in the code, the Secretary of Transportation was responsible to set passenger car standards for the years from 1981 to 1984, and also to set all standards for vehicles other than passenger cars; for example, light trucks and vans. These standards were to be set at the highest feasible level for each year.

On June 24, 1977, the Secretary of Transportation, Mr. Brock Adams, announced the following fuel economy standards for passenger cars (6:1):

22 miles per gallon in 1981
24 miles per gallon in 1982
26 miles per gallon in 1983
27 miles per gallon in 1984
27.5 miles per gallon in 1985

It was also noted by the Secretary that higher standards may apply to 1984 and 1985 years if the technology is present to produce better results. However, a one-half mile per gallon rollback on the standard was granted if the EPA, in their fuel economy test procedure, did not allow the use of so-called slippery oils, commonly known as synthetic oils.

Testimony and other forms of input were called for by the Department of Transportation when it came time to set the standards for light trucks and vans. An initial proposal by Secretary Adams brought heavy response from the automotive corporations, the labor unions, and consumer groups. This original proposal of 20.5 miles per gallon for trucks and vans by 1981 would have cost an estimated 100,000 jobs on a national level and 40,000 jobs in the State of Michigan (3:102).

On March 17, 1978, Secretary Adams announced the following fuel

economy standards for light trucks and vans up to 8,500 pounds gross vehicle weight (3:1):

Two wheel drive

16 miles per gallon in 1980

18 miles per gallon in 1981

Four wheel drive

14 miles per gallon in 1980

15.5 miles per gallon in 1981

One interesting note relating to this standard was that American corporations such as General Motors, Ford, or Chrysler could not include captive imports in their averages. A captive import was a vehicle which was not made in the United States, but was imported and sold by a domestic corporation.

Also, the one-half mile per gallon rollback would be in effect if slippery oils were not allowed by the EPA test procedure.

Truck and van standards for the years 1982 through 1985 are to be set at a later date by the Secretary of Transportation.

Automotive Regulations: Environmental Protection Agency

The Environmental Protection Agency came under much criticism for their mileage guide information. In the guide, each year starting with 1975, every model of car sold in the United States was rated on its city and highway fuel economy. In several of the last years, a combined gas mileage number had also been shown. The problem with the test was that it typically yielded mileages which were higher than the average motorist was able to obtain in a similar car.

For this reason, the Environmental Protection Agency had been

developing a new rating system which yielded more realistic figures. For 1979, only one economy figure was listed and it corresponded to what had been the city mileage test (2:1).

This change in mileage figures did not affect the Corporate Average Fuel Economy figures as required by the Department of Transportation. The average fuel economy for each corporation, through 1985, used the old mileage numbers which were in effect from 1975 through 1978.

III. Progress and Possibilities

With current average fuel economies for 1978 at slightly over the required 18 miles per gallon the question becomes, where would the extra 7.5 miles per gallon be found before 1985?

This question was addressed by a Task Force established by the Energy Resources Council on March 21, 1975 (29:1). The Task Force consisted of representatives from the Department of Transportation, the Environmental Protection Agency, the Energy Research and Development Administration, the Federal Energy Administration, and the National Science Foundation. The work of the Task Force was published in The Report on Motor Vehicle Goals Beyond 1980.

In this report a number of important automotive issues were addressed. Included in the group was the area of fuel economy. The report stated that in the near term (1977-1980), manufacturers should have little trouble meeting the mileage standards provided that the consumer buys cars in the traditional mix of sizes. However, in order to meet the 27.5 miles per gallon figure of 1985, a manufacturer would have to institute one or more of the following steps (29:26):

1. Reduce automobile acceleration well below current norms.

2. Provide incentives which would lead to the sale of a higher percentage of small cars.

3. Adopt a diesel engine in an appreciable percentage of cars.

4. Accelerate the development and introduction of upgraded transmissions.

5. Introduce innovative automobile structures in the early 1980's.

Also, the report estimated the following mileage gains or losses over the average car of 1977 (29:28):

GAINS

Reduce Performance (0-50 in 17 sec)	+2.4mpg
Reduce Performance (0-50 in 20 sec)	+5.0mpg
Reduce Fraction of 6-Passenger Cars (from 50% to 40%)	+0.6mpg
Reduce Fraction of 6-Passenger Cars (from 50% to 30%)	+1.2mpg
Accelerate Upgraded Transmissions	+1.1mpg
Improve Otto Cycle Engine (10%)	+1.2mpg
Dieselize 6-Passenger Cars	+1.3mpg
Shift to Diesel Fleet	+1.9mpg
Accelerate Innovative Structure	+1.3mpg

LOSSES

Introduction of Safety Level II	-1.1mpg
6% Fuel Economy Penalty for Emissions	-1.5mpg
12% Fuel Economy Penalty for Emissions	-3.1mpg
Miscellaneous Weight Increases	-1.9mpg

The report, based on the information shown, estimated a realistic 25.4 miles per gallon was possible by 1985.

IV: Summary

Federal regulation of fuel economy became law in late 1975 and

affected all vehicles to be manufactured from 1977 through 1985.

Whether the automotive companies can meet the regulations, and how much fuel will be saved remains to be seen. Definite progress was being made but it's rate was questionable.

The regulation of fuel economy included cars from 1978 through 1985 and light trucks and vans from 1980 through 1981. The regulation was set as follows:

Passenger Cars

18 miles per gallon in 1978

19 miles per gallon in 1979

20 miles per gallon in 1980

22 miles per gallon in 1981

24 miles per gallon in 1982

26 miles per gallon in 1983

27 miles per gallon in 1984

27.5 miles per gallon in 1985

Light Trucks and Vans

2 wheel drive

16 miles per gallon in 1980

18 miles per gallon in 1981

4 wheel drive

14 miles per gallon in 1980

15.5 miles per gallon in 1981

In addition to these regulations, the Secretary of Transportation had the authority to alter the numbers within certain limitations.

Chapter 8

FUEL ECONOMY CURRICULUM

The curriculum developed as a part of this study was intended to be used in four specific situations at Mankato State University. First, a one-hour unit was organized to be presented to general audiences, not as a portion of any specific course. Then two separate three-hour units were assembled which were intended to be included with existing courses in Basic Automotive Mechanics and Gasoline Engine Technology. Finally, curriculum was developed for a three-credit in-service course on automotive fuel economy.

I. General Audience

This presentation was developed for general audiences. Because the background of the audience could be quite varied, the only assumption made was that each individual in the group was an automobile driver and was basically familiar with the vehicle's use of gasoline and the concept of fuel economy based in mile-per-gallon units.

Audience Background

The groups for which this talk was used were quite diverse. They included university classes, community service groups, energy forums, and county and city employees.

Length of Presentation

The talk was based on a one-hour time period. However, this often

had to be shortened to fit into the allowable time guidelines given by the group.

Method of Instruction

The presentation began with a lecture-style address to establish the background and credibility of the presenter. Visual materials were used for emphasis and direction. The final portion of the talk involved a question-answer session on fuel economy.

Objectives

The general purpose of the talk was to provide information and increase public awareness on the topic of automotive fuel economy.

The specific objectives of the talk were that each individual attending the presentation would:

1. Know the background of the automobile as it was related to energy consumption and cost increases.
2. Be aware of mileage research at Mankato State University.
3. Be able to use the Gas Mileage Guide.
4. Know some possible ways to improve fuel economy on their personal cars.

Topics

I. Introduction
   A. The automobile's role in energy consumption.
   B. Gasoline cost versus the general economy.
   C. Outside influences on the cost of gasoline.
   D. Fuel economy versus safety and emissions.
II. Mankato State University project vehicle summary.
III. Gas Mileage Guide (EPA, DOE)

IV. Mileage improvement

A. Driving habits.

B. Car selection.

C. Maintenance.

D. Aftermarket products.

Audience Activities

No audience activities were used in this presentation. However, question/answer sessions normally followed the formal presentation.

Demonstrations

None were used.

Teaching Aids

The aids used in this presentation included transparencies and slides.

1. The transparencies used followed with the lecture to emphasize points and provide statistical information and graphic comparisons. Twelve full sized visuals were used and a large number of single words or phrases were used to aid in the question/answer sessions.

2. A short slide series was used to show the fuel economy projects from Mankato State University.

Evaluation Procedure

The first two times this presentation was given, the audience consisted of employees of the City of Mankato. Evaluation was conducted by Mr. Phil Sieber, who, representing the city, had contracted for the session. Normally, no evaluation was used.

II. Basic Automotive Mechanics, ITS 231

This fuel economy unit was intended to be used in the Basic Automotive Mechanics course which was taught at Mankato State University. The four quarter hour credit course was an introductory level offering which covered maintenance, selection, and operation of the modern automobile. Included in the course was both vehicle maintenance and related information. The related information covered topics on consumer information, the automotive industry, technical information, and social problems related to the automobile. Fuel economy fit into the content of this course in several ways. Maintenance, car selection, and driving habits all had an affect on vehicle fuel economy. Also, the use of petroleum products by the automobile was an important factor in the cost of vehicle operation and the use of our country's energy resources.

Audience Background

The students enrolled in the course had, by the time the fuel economy unit was presented, a basic technical understanding of the mechanical operation of the automobile. They had studied the four stroke-cycle operation of the automotive engine and knew how fuel was used to produce the power.

Length of Presentation

The unit was organized around a three class-hour bock of time (each class hour lasting fifty minutes) and presented on two consecutive class meeting days.

Method of Instruction

The class presentation made use of the lecture/discussion method.

Teaching aids included slides, transparencies, and information sheets. Three optional student activities were available to be completed outside of class, if the students wanted to apply the activity to the individual work portion of the course, which made up one-third of their final grades.

Objectives

The general purpose of the unit was to introduce the topic of fuel economy, establish its importance, discuss how it was tested and regulated, and explain what could be done to improve it.

The specific objectives of the unit were that each student would:

1. Understand the relationships between the automobile, energy consumption, and outside influences on the cost of gasoline and its availability.

2. Be aware of mileage research projects at Mankato State University.

3. Know how fuel economy could be measured and be able to measure it on their personal cars.

4. Be able to read and understand the results published in the Gas Mileage Guide.

5. Be aware of current fuel economy legislation.

6. Know possible ways to improve gas mileage and know which methods have the most potential and which are cost effective.

Topics

I. Introduction

A. The automobile's role in energy consumption.

B. Gasoline cost versus the general economy.

C. Outside influences on the cost of gasoline.

D. Fuel economy versus safety and emissions.

II. Mankato State University project vehicle summary

III. How fuel economy is measured

A. Basic miles per gallon.

B. Record keeping.

C. Effect and control of variables.

D. Accurate fuel and distance measurement.

E. Alternate units of economy measurement.

IV. Gas Mileage Guide (EPA, DOE)

A. How test is run.

B. How test relates to emission test.

C. How results are reported.

V. Fuel economy legislation

VI. Mileage improvement

A. Driving habits.

B. Car selection.

C. Maintenance.

D. Aftermarket products.

Student Activities

Each of these optional activities involved the students with fuel economy related calculations on their own cars. The three activities included (Appendix B):

1. "Odometer and Speedometer Worksheet" - The student calculated the odometer correction factor for his/her car and also checked the accuracy of his/her speedometer.

2. "Fuel Economy Test" - The student kept fuel economy records on his/her car.

3. "Fuel Economy Test" - The student ran a limited fuel economy test on his/her car.

Demonstrations

None were used.

Teaching Aids

The aids used in this unit included a variety of transparencies, slides, and information sheets.

1. The transparencies used followed the lecture to emphasize points and provide statistical information. Sixteen visuals were used.

2. Two short slide series were developed. One showed the various mileage project cars from Mankato State University while the other showed the EPA test procedure for fuel economy.

3. Three information sheets were used. This topic was not covered in the textbook used for the course. As facts changed on the topic, the information sheets were updated. The sheets used included information on the Gas Mileage Guide, fuel economy legislation, and a procedure sheet on odometer and speedometer correction (Appendix B).

Evaluation Procedure

On a time weighted basis this unit comprised three contact hours of the twenty contact hours covered on the second and final unit test in the course. The total test usually included 70 to 80 total points, of which 10 came from the fuel economy unit. All questions asked were objective in nature, generally using the true-false or multiple choice format. The test was changed each quarter to keep it up-to-date and relevant to the material covered.

III. Gasoline Engine Technology, ITS 431, 531

This unit of instruction was developed as a portion of a three credit course, Gasoline Engine Technology, which emphasized engine design features and experimental procedures used in automotive testing. As a portion of the course, each student was expected to conduct an experiment or research on an automotive topic. While the topic did not have to be fuel economy, students often chose to work in that area. One other topic in the course, automotive emissions, shared some content with the information on fuel economy. Because of this overlap, the two units were usually taught one right after the other.

Audience Background

Students taking the course had completed Basic Automotive Mechanics as a pre-requisite and often had taken other courses, such as Engine Rebuilding or Tune-up and Diagnosis. They, therefore, would have a solid background in engine oepration and maintenance, along with having been introduced to the topic of fuel economy while taking the Basic Automotive Mechanics course. Because the course was also offered for graduate credit, some students in the graduate category would often be teachers in the area of automotive mechanics.

Length of Presentation

The course was always taught as an evening class which would meet one time each week for a three hour block of time. The unit on fuel economy was presented in one three hour block.

Method of Instruction

The class presentation was centered around the lecture/discussion

method with demonstrations added to explain fuel economy measurement procedures and equipment. The students had their option of working on this topic for their research project. Project work was done outside of the normal class meeting time.

Objectives

The general purpose of this unit was to introduce the topic of fuel economy testing and research and show its relationship to automotive engine design.

The specific objectives of the unit were that each student would:

1. Know the design factors which affect the fuel economy of today's cars.

2. Be aware of the procedures and equipment available for accurately measuring fuel economy.

3. Be able to design an adequate test procedure to be used for fuel economy testing.

4. Be familiar with the results of a variety of previous fuel economy tests.

Topics

I. Review of topics
   - A. Fuel economy versus safety and emissions.
   - B. Gas Mileage Guide (EPA, DOE).
   - C. Fuel economy legislation.
   - D. Mankato State University project vehicles.

II. Design factors for fuel economy
   - A. Vehicle size, weight, and air drag.
   - B. Engine type and size.

C. Drive train type and gear ratios.

D. Optimization of vehicle design.

III. Fuel Economy testing

A. Energy efficiency units for various fuels.

B. Energy efficiency units for various vehicles.

C. Distance measurement.

D. Fuel measurement.

E. Environmental measurement.

F. Speed and time measurement.

G. Control of variables.

H. Error determination.

I. Selection of test course.

J. Selection of final test procedure.

IV. Reports on selected economy tests

A. Vehicle speed.

B. Gear ratio.

C. Tire pressure.

D. Various other tests.

Student Activities

No student activities were required for this unit. However, many students in the course chose this area for their individual research project.

Demonstrations

The unit consisted of two demonstrations which took place during class time.

1. Weight measurement of gasoline energy content.

2. Fuel flow on dynomometer and calculation of specific fuel consumption.

Teaching Aids

The aids used in this unit included a variety of transparencies, slides, information sheets and a display of fuel, distance, time and environment measuring equipment.

1. The transparencies used followed the lecture to emphasize points and provide statistical information.

2. Two short slide series were developed to update the Mankato State University project vehicles and to review the EPA fuel economy test procedure.

3. Updated information sheets were used to replace information which students received while taking Basic Automotive Mechanics. Also, information on test procedures and test results were used (Appendix B).

4. Display items included mileage meters, fuel flow meters, odometers, electronic timing devices and weather recording instruments used in fuel economy testing.

Evaluation Procedure

On a time weighted basis this unit comprised three contact hours of the twenty contact hours covered on the second and final unit test in the course. The total test usually included 70 to 80 total points, of which 10 came from the fuel economy unit. All questions asked were objective in nature, generally using the true-false or multiple choice format. The test was changed each quarter to keep it up-to-date and relevant to the material covered.

IV. In-Service: Fuel Economy Testing, ITS 491, 591

The curriculum developed for this three-credit course was intended to be used as a summer offering for individuals involved in teaching automotive courses at the secondary or post-secondary level in either industrial arts or vocational education settings. Because the individuals taking this offering would not usually have taken the Basic Automotive Mechanics or the Gasoline Engine Technology course, the topics covered in those presentations served as the first phase for this course. While each of the previously described instructional units had been used a number of times, this course had not yet been used, but was scheduled for use during the summer of 1979.

Audience Background

The majority of the students in the course were expected to be auto mechanics teachers. This indicated formal education along with a practical background on automotive topics.

Length of Presentation

The course was organized in a ten consecutive day time period with four hours per day listed as the meeting time.

Method of Instruction

The course began with formal presentations on fuel economy and fuel economy testing using the lecture, discussion, and demonstration method.

The second phase of the course involved lab work on mileage testing and curriculum development. During this phase individuals worked in the lab with instructor supervision.

The final portion of the course was devoted to presentations by each student on mileage test results and the curriculum unit each developed.

Objectives

The general purpose of this course was to provide an opportunity for automotive instructors to become updated on the topic of fuel economy, learn how to conduct a fuel economy test, and have the chance to develop a fuel economy teaching unit for their personal teaching situations.

The specific objectives of the course were that each student would:

1. Know the background of automotive fuel economy and obtain up-to-date information on the topic.
2. Know the general areas into which fuel economy improvement ideas fall.
3. Be aware of the major vehicle design factors which influence fuel economy.
4. Design and conduct an accurate fuel economy test.
5. Develop a curriculum unit on fuel economy.

Topics

I. Introduction

II. Fuel Economy

- A. The automobile and energy consumption.
- B. Mankato State University project vehicle summary.
- C. Fuel economy measurement.
- D. Gas Mileage Guide (EPA, DOE).
- E. Fuel economy legislation.

F. Fuel economy improvement (general).

III. Fuel economy design and testing

A. Vehicle design factors.

B. Fuel economy testing procedures and equipment.

C. Reports on selected economy tests.

D. Setting up and running a fuel economy test.

IV. Fuel economy curriculum

A. Available resource materials.

B. Existing curriculum.

C. Curriculum design requirements.

Student Activities

Required student activities included the designing and conducting of a fuel economy test and the development of a teaching unit on fuel economy. Some time was allowed in class for these activities and some of the time was required in addition to the scheduled hours.

Demonstrations

The major demonstration for the course was the actual testing of a fuel economy factor. In addition, several mini-demonstrations centered around the use of mileage measuring apparatus such as flow meters and timers.

Teaching Aids

The aids used in this course included a variety of transparencies, slides, information sheets, and fuel economy measuring apparatus and equipment.

1. The transparencies used followed the lecture to emphasize points and provide statistical information or graphical representation.

2. Two slide series were developed to show the Mankato State University project vehicles and to describe the EPA fuel economy test procedure.

3. Information sheets were used to provide factual information and outline major topics.

4. Fuel economy measuring apparatus and equipment was available to be used by students in their testing.

5. Books, magazines, films, and curriculum units on fuel economy were used for resource materials in the development of the student's teaching units.

Evaluation Procedure

An objective test was developed to evaluate the student in the areas of general fuel economy knowledge and also fuel economy testing procedures. The actual fuel economy test and the teaching unit were subjectively evaluated by the instructor and student using a conference format.

V. Summary

The development of the curriculum in this area was necessitated by the increased importance and the lack of available materials on the topic. The first attempt was to include economy information as a portion of existing topics in the Basic Automotive Mechanics course. This was then developed into a separate unit.

As more knowledge and information was gained on the topic, more teaching material was developed and then integrated into the course on Gasoline Technology. Finally a complete course was organized on the topic which covered background information, testing, and curriculum development.

All units and materials with the exception of the fuel economy

course had been used at Mankato State University in the courses offered by the Industrial Technical Studies Department. Student interest was high in this area and test results indicated that the objectives of the units were achieved.

Chapter 9

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

The study was conducted to examine the topic of automotive fuel economy and develop a set of related teaching units to be used in a typical automotive technology curriculum. The specific application of the units was intended for use in the automotive courses offered by the Industrial Technical Studies Department at Mankato State University.

I. Research Methodology

The study was divided into three areas. Technical and background information on the topic was gathered; curriculum information was sought; and then, curriculum materials were developed and organized.

Technical information on fuel economy was studied in two ways. First, written materials on the subject were gathered and then actual mileage tests were run on selected factors which affected fuel economy. Background on the topic was obtained through written materials, field trips to automotive test facilities, building project cars, and participation in fuel economy contests.

Curriculum information was sought but not found. The search included textbooks, curriculum guides, college catalogs, and automotive industry publications.

Curriculum materials were developed at four levels. A one-hour presentation on fuel economy was organized for general audiences. Two units were assembled for use in courses taught at Mankato State University

One of these units was a three contact hour general presentation for use in a Basic Automotive Mechanics course, while the second unit was a three contact hour specific presentation on fuel economy testing which was used in a course on Gasoline Engine Technology. The final level of curriculum developed was a three credit hour course on Fuel Economy Testing which was to be used as an in-service offering for individuals teaching automotive mechanics at the secondary or post-secondary level.

II. Findings and Conclusions

The findings of the study showed that while a large amount of technical information existed on the topic of fuel economy, no curriculum materials were available. This led to the conclusion that material should be developed to be used in an automotive technology curriculum and also for general public use.

III. Recommendations

The technical and background information presented in this study would need to be kept up-to-date to remain useful. Much research remained in the area of fuel economy testing procedure and the improvement of energy efficiency of the automobile.

The curriculum and materials developed in this study would need adapting to fit into most automotive curriculums but it was hoped that they would be able to serve as a guide and/or starting point for further development by individual instructors.

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APPENDIX A

MILEAGE TEST FORMS AND RESULTS

MILEAGE TEST PROCEDURE

I. TEST SEQUENCE

Determine factor to be tested

Select appropriate vehicle

Check general vehicle state of tune and driveability

Fill out vehicle description form

Fit fuel flow meter and set final tire pressure

Measure–record weather conditions

Run Test #1 in base condition and record data

Make appropriate change for factor being tested

Run Test #2 in changed condition and record data

Run Test #3 in changed condition and record data

Change back to base condition

Run Test #4 in base condition and record data

Measure and record weather conditions

II. ABORT/RE-TEST CONDITIONS

Any run more than $\pm$ ½ mph in speed

Any of the following weather conditions from start to stop of entire test sequence:

1. Temp change of over 10°F
2. Wind change of over 5 mph
3. BP change of over .1" Hg

Any traffic condition which affect speed or wind condition or which caused any lane change

III. STANDARD TEST CONDITIONS

Speed = 55 miles per hour

Transmission = High gear

Engine = Warmed up--driven 10 miles minimum at highway speeds

Windows = Rolled up

TEST #

MILEAGE TEST WORKSHEET

WEATHER

	START	STOP
TEMP		
HUM		
BAR		
WIND		
SKY		

TIME

DATE _____

STOP _____

START _____

TOTAL _____

DRIVER

NAME _____

VEHICLE

MILES FINISH _____

MILES START _____

TOTAL MILES _____

CONDITIONS

BASE COND _____

COND #1 _____

COND #2 _____

RESULTS

RUN	#1	#2	#3	#4	#5	#6
CONDITION						
FUEL (56-61)						
TIME (56-61)						
FUEL (61-56)						
TIME (61-56)						
TOTAL FUEL						
TOTAL TIME						

COMMENTS

TEST #

TEST RESULTS AND CALCULATIONS

	BASE		CONDITION 1		CONDITION 2	
CONDITION						
RUN #						
FUEL USED						
AVE FUEL USED						
AVE MPG						
CHANGE (MPG)						
CHANGE (%)						

TIME (MIN/SEC)						
TIME (DECIMAL)						
MPH						
AVE MPH						
CHANGE (MPH)						
CHANGE (%)						

COMMENTS

TEST # 105

MILEAGE TEST SUMMARY

PURPOSE OF TEST

PROCEDURE

RESULTS

CONCLUSIONS

TEST#

VEHICLE DESCRIPTION

MAKE _____ MODEL _____ YEAR _____

ODOMETER READING _____ GENERAL ENGINE CONDITION _____

MILES SINCE LAST TUNE-UP _____

ENGINE

TYPE _____ HP _____ DISP _____ CR _____

TIMING _____ DWELL _____ IDLE SPEED _____

CARBURETOR TYPE _____

MISCELLANEOUS

REAR AXLE RATIO _____

BRAKE TYPE _____

TRANSMISSION TYPE _____

POWER ACCESSORIES _____

TIRE PRESSURE FRONT _____ REAR _____

TIRE SIZE/TYPE _____

VEHICLE WEIGHT _____ HOW MEASURED _____

MILEAGE FROM PREVIOUS TESTS _____

COMMENTS

107

TEST # 1

MILEAGE TEST SUMMARY

PURPOSE OF TEST

To determine the repeatability of the test procedure for both mileage and speed. This error factor will be used to establish the level of measurable change for future tests.

PROCEDURE

Run a complete set of tests (4 runs) making no changes to the vehicle.

RESULTS

The maximum change in mileage was .1 mpg or .6%.

The maximum change in speed was .4 mph or .8%.

CONCLUSIONS

The test error for future testing is established to be 1% for mileage and 1% for speed.

This does not mean that the test will be assumed to be repeatable from day-to-day. Also no assumption is made to accuracy of mpg ratings.

The test for error factor should be redone at a later date and possibly a different vehicle.

TEST# 1

VEHICLE DESCRIPTION

MAKE Chevrolet MODEL Nova 2dr YEAR 1974

ODOMETER READING 2000 GENERAL ENGINE CONDITION New

MILES SINCE LAST TUNE-UP —

ENGINE

TYPE 6 cyl HP 100 SAE Net DISP 250 cu in CR 8.25 : 1

TIMING 8° BTDC DWELL 31°-34° IDLE SPEED 600 Dr

CARBURETOR TYPE 1 barrel

MISCELLANEOUS

REAR AXLE RATIO NC

BRAKE TYPE Disc Front

TRANSMISSION TYPE Auto

POWER ACCESSORIES P. S.

TIRE PRESSURE FRONT 26 REAR 26

TIRE SIZE/TYPE bias- size not checked

VEHICLE WEIGHT NC HOW MEASURED —

MILEAGE FROM PREVIOUS TESTS EPA 1974 INFO = 15.7 MPG

COMMENTS

MSU Driver Ed Car

TEST # 1

MILEAGE TEST WORKSHEET

WEATHER

	START	STOP
TEMP	52°F	59°F
HUM	60%	61%
BAR	30.46"	30.48"
WIND	None	None
SKY	clear	clear

TIME

DATE 6/26/74

STOP 6:45 Am

START 5:30 Am

TOTAL 1 ¼ hrs.

DRIVER

NAME K. Ready
J. Krause (observer)

VEHICLE

MILES FINISH 2051

MILES START 1990

TOTAL MILES 61

CONDITIONS

BASE COND Standard Test Cond.

COND #1 No change

COND #2 _____

RESULTS

RUN	#1	#2	#3	#4	#5	#6
CONDITION	Base	1	1	Base		
FUEL (56-61)	272	277	273	275		
TIME (56-61)	5:36.5	5:38.6	5:38.9	5:35.2		
FUEL (61-56)	279	277	278	278		
TIME (61-56)	5:38.8	5:37.8	5:36.5	5:36.2		
TOTAL FUEL	551	554	551	553		
TOTAL TIME	11:15.3	11:16.4	11.15.4	11:11.4		

COMMENTS

Driving was done at 55 mph on speedometer

TEST # 1

TEST RESULTS AND CALCULATIONS

	BASE		CONDITION 1		CONDITION 2	
CONDITION	Std. Test Cond		No change			
RUN #	1	4	2	3		
FUEL USED	551	553	554	551		
AVE FUEL USED	.552		.5525			
AVE MPG	18.12		18.10			
CHANGE (MPG)	—		.02			
CHANGE (%)	—		.1 %			

TIME (MIN/SEC)	11:15.3	11:11.4	11:16.4	11:15.4		
TIME (DECIMAL)	675.3	671.4	676.4	675.4		
MPH	53.31	53.62	53.22	53.30		
AVE MPH	53.46		53.26			
CHANGE (MPH)	——		−.20			
CHANGE (%)			.4 %			

COMMENTS

The best single mileage was 18.15
The worst " " " 18.05

Maximum error = .1 mpg = .6 %

The fastest single speed was 53.62
The slowest single speed was 53.22

Maximum error = .4 mph = .8 %

111

TEST # 2

MILEAGE TEST SUMMARY

PURPOSE OF TEST

To determine the effect of reversing the top on the air cleaner, thus allowing cold, unrestricted air to enter the carburetor.

PROCEDURE

The car was run with the air cleaner in the standard position and also run with the top section of the air cleaner turned over and bolted in place.

RESULTS

Having the air cleaner reversed did improve the mileage by 2%.

CONCLUSIONS

While the gain was present, it was small. Also the technique of air cleaner reversal will probably not work as well in stop-and-go driving cycles or in cold weather. In addition, the procedure involves some fire hazard and also defeats part of the emission control system. The same results should be available by switching the jetting of the carburetor.

TEST# 2

VEHICLE DESCRIPTION

MAKE Chevrolet MODEL Nova 2dr YEAR 1974

ODOMETER READING 2075 GENERAL ENGINE CONDITION New

MILES SINCE LAST TUNE-UP —

ENGINE

TYPE 6 cyl HP 100 SAE Net DISP 250 cu in CR 8.25:1

TIMING 8° BTDC DWELL 31°-34° IDLE SPEED 600 Dr

CARBURETOR TYPE 1 barrel

MISCELLANEOUS

REAR AXLE RATIO NC

BRAKE TYPE Disc Front

TRANSMISSION TYPE Auto

POWER ACCESSORIES P.S.

TIRE PRESSURE FRONT 26 REAR 26

TIRE SIZE/TYPE bias - size not checked

VEHICLE WEIGHT NC HOW MEASURED —

MILEAGE FROM PREVIOUS TESTS EPA 1974 In Fo = 15.7 mpg

COMMENTS

MSU Driver Ed Car

TEST # 2

MILEAGE TEST WORKSHEET

WEATHER

	START	STOP
TEMP	60°F	65°F
HUM	55%	55%
BAR	30.35"	30.40"
WIND	Little	5mph From south
SKY	Clear	Clear

TIME

DATE 6/27/74

STOP 7:30

START 6:00

TOTAL 1½ hrs

DRIVER

NAME K. Ready

VEHICLE

MILES FINISH 2129

MILES START 2075

TOTAL MILES 54

CONDITIONS

BASE COND Standard Test Condition

COND #1 Air Cleaner Top Reversed

COND #2 —

RESULTS

RUN	#1	#2	#3	#4	#5	#6
CONDITION	BASE	1	1	BASE		
FUEL (56-61)	277	273	265	273		
TIME (56-61)	5:26.7	5:28.0	5:26.8	5:25.4		
FUEL (61-56)	278	277	270	279		
TIME (61-56)	5:29.9	5:29.8	5:29.8	5:27.5		
TOTAL FUEL	555	550	535	552		
TOTAL TIME	10:56.6	10:57.8	10:56.6	10:52.9		

COMMENTS

Wind was starting to blow during run 3 + 4.

124

TEST # 2

TEST RESULTS AND CALCULATIONS

	BASE		CONDITION 1		CONDITION 2	
CONDITION	Std. Test Cond.		Air Cleaner Rev.			
RUN #	1	4	2	3		
FUEL USED	555	552	550	535		
AVE FUEL USED	.5535		.5425			
AVE MPG	18.07		18.43			
CHANGE (MPG)	—		+ .36 mpg			
CHANGE (%)	—		+ 2.0 %			

TIME (MIN/SEC)	10:56.6	10:52.9	10:57.8	10:56.6		
TIME (DECIMAL)	656.6	652.9	657.8	656.6		
MPH	54.83	55.19	54.73	54.83		
AVE MPH	54.98		54.78			
CHANGE (MPH)	—		- .20			
CHANGE (%)	—		- .4 %			

COMMENTS

TEST # 3

MILEAGE TEST SUMMARY

PURPOSE OF TEST

To determine the effect of vehicle speed on fuel economy.

PROCEDURE

Drive the car at 45, 55, and 65 miles per hour.

RESULTS

Using the 55 mph run as a base, the fuel economy dropped by 10.5% when the car was going 65 mph and improved by 11.1% when the speed was lowered to 45 mph.

CONCLUSIONS

Vehicle speed is a very important factor in fuel economy. Note - the 3.84 mile per gallon difference between 45 mph and 65 mph. This amounts for a 24.1% gain in mileage by slowing down 20 mph.

TEST# 3

VEHICLE DESCRIPTION

MAKE Chevrolet MODEL Nova YEAR 1974

ODOMETER READING 2140 GENERAL ENGINE CONDITION New

MILES SINCE LAST TUNE-UP —

ENGINE

TYPE 6 cyl HP 100 SAE Net DISP 250 cu in. CR 8.25:1

TIMING 8° BTDC DWELL 31°-34° IDLE SPEED 600 Dr

CARBURETOR TYPE 1 barrel

MISCELLANEOUS

REAR AXLE RATIO NC

BRAKE TYPE Disc Front

TRANSMISSION TYPE Auto

POWER ACCESSORIES P. S.

TIRE PRESSURE FRONT 26 REAR 26

TIRE SIZE/TYPE bias - size not checked

VEHICLE WEIGHT NC HOW MEASURED —

MILEAGE FROM PREVIOUS TESTS EPA 1974 In Fo = 15.7 MPG

COMMENTS MSU Driver Ed Car

TEST # 3

MILEAGE TEST WORKSHEET

WEATHER

	START	STOP
TEMP	59°F	67°F
HUM	56%	53%
BAR	30.40"	30.40"
WIND	5-10 mph B	5-10 mph S
SKY	clear+sun	→

TIME

DATE 6/28/74

STOP 8:15 Am

START 5:45 Am

TOTAL 2½ hrs.

DRIVER

NAME K. Ready

VEHICLE

MILES FINISH 2228

MILES START 2142

TOTAL MILES 86

CONDITIONS

BASE COND 55 MPH

COND #1 65 MPH

COND #2 45 MPH

RESULTS

RUN	#1	#2	#3	#4	#5	#6
CONDITION	BASE	1	2	1	2	BASE
FUEL (56-61)	276	306	249	308	253	279
TIME (56-61)	5:26.8	4:39.2	6:44.4	4:38.8	6:44.7	5:27.8
FUEL (61-56)	286	322	255	319	254	282
TIME (61-56)	5:30.1	4:39.8	6:42.6	4:42.1	6:43.3	5:29.2
TOTAL FUEL	562	628	504	627	507	561
TOTAL TIME	10:56.9	9:19.0	13:27.0	9:20.9	13:28.0	10:58.0

COMMENTS

TEST # 3

TEST RESULTS AND CALCULATIONS

	BASE		CONDITION 1		CONDITION 2	
CONDITION	55 MPH		65 MPH		45 MPH	
RUN #	1	6	2	4	3	5
FUEL USED	512	561	628	627	504	507
AVE FUEL USED	.5615		.6275		.5055	
AVE MPG	17.81		15.94		19.78	
CHANGE (MPG)	—		-1.87		+1.97	
CHANGE (%)	—		-10.5%		+11.1%	

TIME (MIN/SEC)	10:56.9	10:57.0	9:19.0	9:20.9	13:27.0	13:28.0
TIME (DECIMAL)	656.9	657.0	559.0	560.9	807.0	808.0
MPH	54.80	54.79	64.40	64.18	44.61	44.55
AVE MPH	54.80		64.29		44.58	
CHANGE (MPH)	—		+9.49 mph		-10.22 mph	
CHANGE (%)	—		+17.3%		-18.6%	

COMMENTS

TEST 4

MILEAGE TEST SUMMARY

PURPOSE OF TEST

To determine the effect of power steering on fuel economy.

PROCEDURE

Run test with power steering hooked-up and then run test with power steering belt removed.

RESULTS

The change in mileage well below the 1% error assumed for the test procedure. Therefore, there was no significant change with or without the power steering.

CONCLUSIONS

While no change was evident, none was expected. The results may prove different on a test course which requires turning maneuvers. The only real disadvantages of power steering may be weight, original cost, and maintenance.

TEST# 4

VEHICLE DESCRIPTION

MAKE Chevrolet MODEL Nova 2dr YEAR 1974

ODOMETER READING 2265 GENERAL ENGINE CONDITION New

MILES SINCE LAST TUNE-UP —

ENGINE

TYPE 6 cyl HP 100 SAE Net DISP 250 cu in CR 8.25:1

TIMING 8° BTDC DWELL 31°-34° IDLE SPEED 600 Dr.

CARBURETOR TYPE 1 barrel

MISCELLANEOUS

REAR AXLE RATIO NC

BRAKE TYPE Disc Front

TRANSMISSION TYPE Auto

POWER ACCESSORIES P. S.

TIRE PRESSURE FRONT 26 REAR 26

TIRE SIZE/TYPE bias - size not checked

VEHICLE WEIGHT NC HOW MEASURED —

MILEAGE FROM PREVIOUS TESTS EPA 1974 Info: 15.7 MPG

COMMENTS

MSU Driver Ed Car

TEST # 4

MILEAGE TEST WORKSHEET

WEATHER

	START	STOP
TEMP	64°F	67°F
HUM	64%	64%
BAR	30.32"	30.34"
WIND	Light	5-10MPH
SKY	Clear+Sun →	

TIME

DATE 7/2/74

STOP 7:30 Am

START 5:45 Am

TOTAL 1 3/4 hrs

DRIVER

NAME K. Ready

VEHICLE

MILES FINISH 2712

MILES START 2669

TOTAL MILES 43

CONDITIONS

BASE COND Std. Test Cond

COND #1 Power Steering Belt OFF

COND #2

RESULTS

RUN	#1	#2	#3	#4	#5	#6
CONDITION	BASE	1	1	BASE		
FUEL (56-61)	263	262	265	264		
TIME (56-61)	5:30.4	5:32.2	5:31.3	5:28.9		
FUEL (61-56)	273	271	270	272		
TIME (61-56)	5:31.2	5:29.3	5:31.8	5:31.8		
TOTAL FUEL	536	533	535	536		
TOTAL TIME	11.01.6	11:01.5	11:03.1	11:00.7		

COMMENTS The car is extremely hard to steer w/o the power steering.

TEST # 4

TEST RESULTS AND CALCULATIONS

	BASE		CONDITION 1		CONDITION 2	
CONDITION	Std Test Con		P.S. Belt OFF			
RUN #	1	4	2	3		
FUEL USED	536	536	533	535		
AVE FUEL USED	.536		.534			
AVE MPG	18.66		18.73			
CHANGE (MPG)	—		+.07 mpg			
CHANGE (%)	—		+.4%			
TIME (MIN/SEC)	11:01.6	11:00.7	11:01.5	11:03.1		
TIME (DECIMAL)	661.6	660.7	661.5	663.1		
MPH	54.41	54.49	54.42	54.29		
AVE MPH	54.45		54.40			
CHANGE (MPH)	—		-.05 mph			
CHANGE (%)	—		-.1%			

COMMENTS

123

TEST # 5

MILEAGE TEST SUMMARY

PURPOSE OF TEST

To determine the effect of having the windows rolled up or down on fuel economy.

PROCEDURE

Run a set of tests with the windows up as the base line and then run with the windows down.

RESULTS

The loss of 1.5% with the windows down was small but still larger than the test error factor.

CONCLUSIONS

The loss can be recovered by using air conditioning and driving with the windows up. Air conditioning; however, will decrease your fuel economy. The net effect is still a loss but by having the windows up the loss of mileage is somewhat offset.

TEST# 5

VEHICLE DESCRIPTION

MAKE Chevrolet MODEL Nova 2dr YEAR 1974

ODOMETER READING 2720 GENERAL ENGINE CONDITION New

MILES SINCE LAST TUNE-UP —

ENGINE

TYPE 6 cyl HP 100 SAE Net DISP 250 cu in CR 8.25:1

TIMING 8° BTDC DWELL 31°-34° IDLE SPEED 600 Or.

CARBURETOR TYPE 1 barrel

MISCELLANEOUS

REAR AXLE RATIO NC

BRAKE TYPE Disc Front

TRANSMISSION TYPE Auto

POWER ACCESSORIES P. S.

TIRE PRESSURE FRONT 26 REAR 26

TIRE SIZE/TYPE bias - size not checked

VEHICLE WEIGHT NC HOW MEASURED —

MILEAGE FROM PREVIOUS TESTS EPA 1974 J.F.D. = 15.7 MPG

COMMENTS MSU Driver Ed Car

TEST # 5

MILEAGE TEST WORKSHEET

WEATHER

	START	STOP
TEMP	59°F	64°F
HUM	60%	60%
BAR	30.46"	30.46"
WIND	L.+1/2	L.+1/2
SKY	Clear-Sun →	

TIME

DATE 7/3/74

STOP 8:00 Am

START 6:30 Am

TOTAL 1½ hrs

DRIVER

NAME K. Ready

VEHICLE

MILES FINISH 2778

MILES START 2724

TOTAL MILES 54

CONDITIONS

BASE COND Windows up

COND #1 Windows down

COND #2 _____

RESULTS

RUN	#1	#2	#3	#4	#5	#6
CONDITION	BASE	1	1	BASE		
FUEL (56-61)	273	280	277	275		
TIME (56-61)	5:32.1	5:31.5	5:34.2	5:34.2		
FUEL (61-56)	278	282	282	278		
TIME (61-56)	5:33.2	5:32.5	5:34.9	5:32.2		
TOTAL FUEL	551	562	559	553		
TOTAL TIME	11.05.3	11:04.0	11:09.1	11:06.4		

COMMENTS Car is dark color - heats up quickly with windows up and sun out.

TEST # 5

TEST RESULTS AND CALCULATIONS

	BASE		CONDITION 1		CONDITION 2	
CONDITION	Windows up		Windows down			
RUN #	1	4	2	3		
FUEL USED	551	553	562	559		
AVE FUEL USED	.552		.5605			
AVE MPG	18.12		17.84			
CHANGE (MPG)	—		+ .28 mpg			
CHANGE (%)	—		+1.5%			

TIME (MIN/SEC)	11:05.3	11:06.4	11:04.0	11:09.1		
TIME (DECIMAL)	665.3	666.4	664.0	669.1		
MPH	54.11	54.02	54.22	53.80		
AVE MPH	54.06		54.01			
CHANGE (MPH)	—		−.05 mph			
CHANGE (%)	—		−.1%			

COMMENTS

TEST # 6

MILEAGE TEST SUMMARY

PURPOSE OF TEST

To determine the effect of tire pressure on fuel economy.

PROCEDURE

Tests were run at the factory recommended pressure of 26 PSI and also at 10 PSI over inflated (36 PSI) and 10 PSI under inflated (16 PSI).

RESULTS

Using the factory recommended pressure as the base, over inflation improved the mileage by 1.6% and under inflation worsened the mileage by 4.8%.

CONCLUSIONS

The mileage benefit of over inflating tires is not very great, and from the cost standpoint, the increased tire wear in the center would be costly. Also a hard ride and possible poor safety condition would exist.

The mileage loss from under inflation is fairly great. Also a definite unsafe condition exists with underinflation.

For the best combination of fuel economy, tire wear, and safety, tires should be inflated to the manufacturer's recommended pressure or no higher than the maximum pressure listed on the sidewall of the tire.

TEST# 6

VEHICLE DESCRIPTION

MAKE Chevrolet MODEL Nova 2dr YEAR 1974

ODOMETER READING 2800 GENERAL ENGINE CONDITION New

MILES SINCE LAST TUNE-UP —

ENGINE

TYPE 6 cyl HP 100 SAE Net DISP 250 cu. in. CR 8.25 : 1

TIMING 8° BTDC DWELL 31°-34° IDLE SPEED 600 Dr

CARBURETOR TYPE 1 barrel

MISCELLANEOUS

REAR AXLE RATIO NC

BRAKE TYPE Disc Front

TRANSMISSION TYPE Auto

POWER ACCESSORIES P.S.

TIRE PRESSURE FRONT 26 REAR 26

TIRE SIZE/TYPE bias - size not checked

VEHICLE WEIGHT NC HOW MEASURED —

MILEAGE FROM PREVIOUS TESTS EPA 1974 Info = 15.7 mpg

COMMENTS

MSU Driver Ed Car

TEST # 6

MILEAGE TEST WORKSHEET

WEATHER

	START	STOP
TEMP	57°F	65°F
HUM	62%	62%
BAR	30.35"	30.35"
WIND	NONE	NONE
SKY	clear	clear

TIME

DATE 7/5/74

STOP 7:30 Am

START 5:30 Am

TOTAL 2 hours

DRIVER

NAME K. Ready

VEHICLE

MILES FINISH 2869.6

MILES START 2802.7

TOTAL MILES 66.9

CONDITIONS

BASE COND T.P. = 26 PSI

COND #1 T.P. = 36 PSI

COND #2 TP = 16 PSI

RESULTS

RUN	#1	#2	#3	#4	#5	#6
CONDITION	Base	1	2	2	1	Base
FUEL (56-61)	278	272	295	297	273	276
TIME (56-61)	5:28.23	5:26.32	5:2	:25.14	5:25.01	5:26.02
FUEL (61-56)	272	270	282	281	266	273
TIME (61-56)	5:26.92	5:27.89	5:25.23	5:27.56	5:26.87	5:27.08
TOTAL FUEL	550	542	577	578	539	549
TOTAL TIME	10:54.67	10:54.21	10:53.12	10:52.69	10:51.88	10:53.10

COMMENTS

TEST # 6

TEST RESULTS AND CALCULATIONS

	BASE		CONDITION 1		CONDITION 2	
CONDITION	TP = 26 PSI		TP = 36 PSI		TP = 16 PSI	
RUN #	1	6	2	5	3	4
FUEL USED	550	549	542	539	577	578
AVE FUEL USED	.5495		.5405		.5775	
AVE MPG	18.20		18.50		17.32	
CHANGE (MPG)	—		+.30		−.88	
CHANGE (%)	—		+1.6%		−4.8%	

TIME (MIN/SEC)	10:54.67	10:53.10	10:54.21	10:51.88	10:53.12	10:52.64
TIME (DECIMAL)	654.67	653.10	654.21	651.88	653.12	652.64
MPH	54.99	55.12	55.03	55.22	55.12	55.16
AVE MPH	55.06		55.13		55.14	
CHANGE (MPH)	—		.07		.08	
CHANGE (%)	—		.1%		.1%	

COMMENTS

TEST # 7

MILEAGE TEST SUMMARY

PURPOSE OF TEST

To determine the effect of using an air conditioner.

PROCEDURE

Run the test with the air conditioner turned off and then run it with the air conditioner turned on.

RESULTS

The car tested got 4.3% worse gas mileage with the air conditioner turned on.

CONCLUSIONS

The 4.3% could be reduced by the loss for having the windows down in a car without an air conditioner, (1.5%). However, this test did not disconnect the belts or remove the extra weight to fully simulate a non air conditioned car. In hot climates, driver fatigue is another outside factor.

TEST# 7

VEHICLE DESCRIPTION

MAKE Chevrolet MODEL Monte Carlo 2dr YEAR 1973

ODOMETER READING 25789 GENERAL ENGINE CONDITION Good

MILES SINCE LAST TUNE-UP Approx 3000 miles

ENGINE

TYPE V-8 HP 145 SAE Net DISP 350 cu in CR 8.5 : 1

TIMING 8° BTDC DWELL 29°-31° IDLE SPEED 600 Dr.

CARBURETOR TYPE 2 barrel

MISCELLANEOUS

REAR AXLE RATIO NC

BRAKE TYPE disc. Front

TRANSMISSION TYPE Auto

POWER ACCESSORIES A.C., P.S., P.B.

TIRE PRESSURE FRONT 30 REAR 30

TIRE SIZE/TYPE NC - standard size

VEHICLE WEIGHT NC HOW MEASURED —

MILEAGE FROM PREVIOUS TESTS owner reports 14 MPG on trips

COMMENTS

TEST # 7

MILEAGE TEST WORKSHEET

WEATHER

	START	STOP
TEMP	73°F	78°F
HUM	65%	63%
BAR	29.92"	29.99"
WIND	10MPH(N)	10-15 MPH(N)
SKY	cloudy →	

TIME

DATE 7/30/75

STOP 8:30 Am

START 7:15 Am

TOTAL 1¼ hrs

DRIVER

NAME K. Ready

VEHICLE

MILES FINISH 25847

MILES START 25792

TOTAL MILES 55

CONDITIONS

BASE COND A/C OFF

COND #1 A/C on

COND #2 _____

Note: windows up For both tests

RESULTS

RUN	#1	#2	#3	#4	#5	#6
CONDITION	BASE	1	1	BASE		
FUEL (56-61)	335	351	349	338		
TIME (56-61)	5:30.2	5:32.1	5:30.1	5'31.8		
FUEL (61-56)	330	347	344	329		
TIME (61-56)	5:31.4	5:29.8	5:29.8	5:27.4		
TOTAL FUEL	665	698	693	667		
TOTAL TIME	10:01.6	11:01.9	10:59.9	10:59.2		

COMMENTS

TEST # 7

TEST RESULTS AND CALCULATIONS

	BASE		CONDITION 1		CONDITION 2	
CONDITION	A/C OFF		A/C ON			
RUN #	1	4	2	3		
FUEL USED	665	667	698	693		
AVE FUEL USED	.666		.6955			
AVE MPG	15.02		14.38			
CHANGE (MPG)	—		− .64 mpg			
CHANGE (%)	—		− 4.3%			

TIME (MIN/SEC)	11:01.6	10:59.2	11:01.9	10:59.9		
TIME (DECIMAL)	661.6	659.2	661.9	659.9		
MPH	54.41	54.61	54.39	54.55		
AVE MPH	54.51		54.47			
CHANGE (MPH)	—		− .04 mph			
CHANGE (%)	—		− .1%			

COMMENTS

TEST # 8

MILEAGE TEST SUMMARY

PURPOSE OF TEST

To determine the effect of weight on fuel economy.

PROCEDURE

Six-hundred pounds of weight was added to the car using bags of salt. This amounted to an extra 29%.

RESULTS

Very little difference was noted. The additional weight reduced the mileage by only 2%.

CONCLUSIONS

Weight, if it does not change the shape of the car, does not have a large effect on fuel economy at highway speeds. However, it could have a greater effect in stop-and-go driving. Large cars do weigh more than small cars but the poorer fuel economy has more to do with wind resistance than weight at highway speeds and steady driving.

TEST# 8

VEHICLE DESCRIPTION

MAKE Fiat MODEL X 1/9 YEAR 1976

ODOMETER READING 4000 GENERAL ENGINE CONDITION New

MILES SINCE LAST TUNE-UP —

ENGINE

TYPE 4 cyl HP 61 SAE Net DISP 1290 c.c. CR 8.5 : 1

TIMING 0° DWELL 55° ± 3° IDLE SPEED 850 RPM

CARBURETOR TYPE 2 barrel - 2 stage

MISCELLANEOUS

REAR AXLE RATIO 4.42 : 1

BRAKE TYPE 4 wheel disc

TRANSMISSION TYPE 4 speed 3rd = 1.454 : 1 4th = .959 : 1

POWER ACCESSORIES None

TIRE PRESSURE FRONT 26 REAR 29

TIRE SIZE/TYPE 145 SR 13 Radial

VEHICLE WEIGHT 2035 HOW MEASURED MSU scale

MILEAGE FROM PREVIOUS TESTS EPA Hwy 31 C.ty 21 Comb 25

COMMENTS St. 11 has 4 cyl engine MSU Project Car

TEST # 8

MILEAGE TEST WORKSHEET

WEATHER

	START	STOP
TEMP	72°F	76°F
HUM	65%	65%
BAR	30.25"	30.25"
WIND	1, +Hz	1, +Hz
SKY	clear	clear

TIME

DATE 7/12/76

STOP 8:00 Am

START 6:00 Am

TOTAL 2 hrs

DRIVER

NAME K. Ready

Observer J. Krause

VEHICLE

MILES FINISH 4089

MILES START 4025

TOTAL MILES 64

CONDITIONS

BASE COND Std Test Cond

COND #1 Addition of 600 lbs

COND #2 _____

RESULTS

RUN	#1	#2	#3	#4	#5	#6
CONDITION	BASE	1	1	BASE		
FUEL (56-61)	156	160	159	157		
TIME (56-61)	5:27.1	5:28.3	5:29.2	5:29.8		
FUEL (61-56)	158	161	163	159		
TIME (61-56)	5.29.3	5:28.9	5:28.9	5:28.8		
TOTAL FUEL	314	321	322	316		
TOTAL TIME	10:56.4	10:57.2	10:58.1	10:58.6		

COMMENTS

TEST # 8

TEST RESULTS AND CALCULATIONS

	BASE		CONDITION 1		CONDITION 2	
CONDITION	w/o weight		w/ 600 lbs			
RUN #	1	4	2	3		
FUEL USED	314	316	321	322		
AVE FUEL USED	.315		.3215			
AVE MPG	31.75		31.10			
CHANGE (MPG)	—		— .65 mpg			
CHANGE (%)	—		— 2.0%			

TIME (MIN/SEC)	10:56.4	10:58.6	10:57.2	10:58.1		
TIME (DECIMAL)	656.4	658.6	657.2	658.1		
MPH	54.84	54.66	54.78	54.70		
AVE MPH	54.75		54.74			
CHANGE (MPH)	—		.01 mph			
CHANGE (%)	—		0.0%			

COMMENTS

TEST # 9

MILEAGE TEST SUMMARY

PURPOSE OF TEST

To determine the effect which larger diameter tires have on fuel economy and to estimate the effect of different gear ratios on fuel economy.

PROCEDURE

The standard rear tires were used as the base test and then were switched to much larger tires. Both sets of tires were of radial construction and were inflated to the same pressure. The large rear tires reduced the engine speed at 55 mph by almost 25%.

RESULTS

The larger tires showed a mileage gain of 17.5% over the smaller tires. While driving the vehicle a loss of power was evident with the larger tires but they caused no handling problems during the test.

CONCLUSIONS

Larger tires do improve fuel economy. The engine slowed down almost 1,000 rpm at the highway speed of 55 mph. This same result should be possible by changing the final drive ratio with either an overdrive in the transmission or a higher gear ratio in the differential. The same rpm drop could be accomplished by changing the final drive ratio from it's present 4.23878:1 to a higher 3.21:1 ratio.

TEST# 9

VEHICLE DESCRIPTION

MAKE Fiat MODEL X 1/9 YEAR 1976

ODOMETER READING 4090 GENERAL ENGINE CONDITION New

MILES SINCE LAST TUNE-UP —

ENGINE

TYPE 4cyl HP 61 SAE Net DISP 1290 cc CR 8.5 : 1

TIMING 0° DWELL 55° ± 3° IDLE SPEED 850 RPM

CARBURETOR TYPE 2 barrel - 2 stage

MISCELLANEOUS

REAR AXLE RATIO 4.42 : 1

BRAKE TYPE 4 wheel disc

TRANSMISSION TYPE 4 speed 3rd = 1.454 : 1 4th = .959 : 1

POWER ACCESSORIES None

TIRE PRESSURE FRONT 26 REAR 29

TIRE SIZE/TYPE Front = 145 SR-13 Radial Rear = Item being tested

VEHICLE WEIGHT 2035 HOW MEASURED MSU scale

MILEAGE FROM PREVIOUS TESTS EPA = Hwy 31 City 21 Comb 25

COMMENTS

MSU Project Car

TEST # 9

MILEAGE TEST WORKSHEET

WEATHER

	START	STOP
TEMP	63°F	68°F
HUM	60%	60%
BAR	30.29	30.32
WIND	Little	Little
SKY	cloudy	cloudy

TIME

DATE 7/13/76

STOP 7:30 AM

START 5:30 AM

TOTAL 2 hrs

DRIVER

NAME K. Ready

VEHICLE

MILES FINISH 4152

MILES START 4098

TOTAL MILES 54

CONDITIONS

BASE COND S.T.C. -Tires 145 SR-13

COND #1 Rear Tires 6.50-16

COND #2 _____

RESULTS

RUN	#1	#2	#3	#4	#5	#6
CONDITION	BASE	1	1	BASE		
FUEL (56-61)	156	131	133	158		
TIME (56-61)	5:29.8	5:26.2	5:26.7	5:28.2		
FUEL (61-56)	154	133	134	156		
TIME (61-56)	5:28.5	5:26.8	5:28.3	5:29.8		
TOTAL FUEL	310	264	267	314		
TOTAL TIME	10:58.3	10:53.0	10:55.0	10:58.1		

COMMENTS

Odometer + speedometer did not register correctly with large tires. Used tacometer 55 mph w/small tires = 3700 RPM
55 mph w/large tires = 2750 RPM

TEST # 9

TEST RESULTS AND CALCULATIONS

	BASE		CONDITION 1		CONDITION 2	
CONDITION	145 SR-13 Tires		6.50-16 Rear Tires			
RUN #	1	4	2	3		
FUEL USED	310	314	264	267		
AVE FUEL USED	.312		.2655			
AVE MPG	32.05		37.66			
CHANGE (MPG)	—		+5.61 mpg			
CHANGE (%)	—		+ 17.5 %			

TIME (MIN/SEC)	10:58.3	10:58.1	10:53.0	10:55.0		
TIME (DECIMAL)	658.3	658.1	653.0	655.0		
MPH	54.69	54.70	55.13	54.96		
AVE MPH	54.70		55.04			
CHANGE (MPH)	—		+ .34 mph			
CHANGE (%)	—		+ .6%			

COMMENTS

TIRE DATA

	Standard 145 SR-13	Larger 6.50-16
overall width	5.8"	6.9"
outside dia.	22.2"	29.2"
loaded radius	10.1"	13.5"
revs per mile	936	709
eng RPM @ 55mph	3637	2755

143

TEST # 10

MILEAGE TEST SUMMARY

PURPOSE OF TEST

To determine the effect of an overdrive transmission on fuel economy.

PROCEDURE

The vehicle used had a four speed transmission in which third gear was a 1:1 ratio and fourth gear was a .73:1 overdrive ratio. To simulate a non-overdrive transmission, the vehicle was driven in third gear. Then fourth gear was used to provide the overdrive.

RESULTS

The overdrive ratio yielded 19.1% better mileage than the non overdrive ratio.

CONCLUSIONS

A significant gain is available by changing gear ratios. However, because the vehicle cannot always be driven in overdrive the total gain for each tank of gas will be less than was obtained in the straight 55 mph test. Overdrive would be of no benefit in city stop-and-go traffic.

TEST# 10

VEHICLE DESCRIPTION

MAKE Dodge MODEL Van B100 YEAR 1977

ODOMETER READING 5860 GENERAL ENGINE CONDITION New

MILES SINCE LAST TUNE-UP —

ENGINE

TYPE 6 cyl HP 100 SAE Net DISP 225cu in. CR 8.4:1

TIMING 12° BTDC DWELL None — Electronic IDLE SPEED 700 RPM

CARBURETOR TYPE 1 barrel

MISCELLANEOUS

REAR AXLE RATIO 3.55:1

BRAKE TYPE Disc. Front

TRANSMISSION TYPE 4sp O.D. 3rd = 1:1 4th = .73:1

POWER ACCESSORIES P. B.

TIRE PRESSURE FRONT 32 REAR 32

TIRE SIZE/TYPE 215 x 15 Radial

VEHICLE WEIGHT 3985 HOW MEASURED MSU scale

MILEAGE FROM PREVIOUS TESTS EPA Hwy 20 City 12 Comb 16

COMMENTS

TEST # 10

MILEAGE TEST WORKSHEET

WEATHER

	START	STOP
TEMP	55°F	59°F
HUM	80%	80%
BAR	29.58"	29.58"
WIND	little	little
SKY	cloudy	cloudy

TIME

DATE 8/11/77
STOP 7:30 Am
START 6:00 Am
TOTAL 1½ hrs

DRIVER

NAME K. Ready

VEHICLE

MILES FINISH 5914
MILES START 5870
TOTAL MILES 44

CONDITIONS

BASE COND 3rd gear
COND #1 4th gear (O.D.)
COND #2 _____

RESULTS

RUN	#1	#2	#3	#4	#5	#6
CONDITION	BASE	1	1	BASE		
FUEL (56-61)	262	219	218	259		
TIME (56-61)	5:29.2	5:28.7	5:28.1	5:30.2		
FUEL (61-56)	260	217	217	257		
TIME (61-56)	5:30.1	5:30.5	5:30.9	5:27.8		
TOTAL FUEL	522	436	435	516		
TOTAL TIME	10:59.1	10:59.2	10:59.0	10:58.0		

COMMENTS Vac. gauge dropped from 10" Hg in 3rd to 5" Hg in 4th - indicates engine working harder in O.D.

TEST # 10

TEST RESULTS AND CALCULATIONS

	BASE		CONDITION 1		CONDITION 2	
CONDITION	3rd Gear		4th gear (OD)			
RUN #	1	4	2	3		
FUEL USED	522	516	436	435		
AVE FUEL USED	.519		.4355			
AVE MPG	19.27		22.96			
CHANGE (MPG)	—		+ 3.69 mpg			
CHANGE (%)	—		+19.1%			

TIME (MIN/SEC)	10:59.1	10:58.0	10:59.2	10:59.0		
TIME (DECIMAL)	659.1	658.0	659.2	659.0		
MPH	54.62	54.71	54.61	54.63		
AVE MPH	54.66		54.62			
CHANGE (MPH)	—		- .04 mph			
CHANGE (%)	—		-.1%			

COMMENTS

APPENDIX B

CURRICULUM MATERIALS

HOW TO CORRECT YOUR ODOMETER AND SPEEDOMETER

In many autos the odometer and/or the speedometer are not accurately calibrated. Many items such as tire size, gear ratios, speedometer gear, or tire pressure, can effect the accuracy of these units. Usually both the speedomter and odometer will error in the same direction, but this is not always true. The following procedure can be used to determine the odometer and speedometer accuracy on your car and also provide a way of compensating for any error you may find.

Odometer Correction Factor (OCF)

The odometer correction factor is a number which when multiplied times the odometer miles traveled yield, the true distance traveled.

Method:

1. Drive a section of road which is 10 miles long - use the roadside mile markers
2. At the beginning and end of the 10 mile run, read and record your odometer reading
3. Use the following formula to determine your OCF

$$OCF = \frac{\text{True Miles}}{\text{Odometer Miles}}$$

4. To determine the miles you have traveled on any trip, multiply your odometer miles times the OCF
5. If used to determine MPG use the OCF to determine true miles before calculating your MPG

*Note: The following can effect your OCF - A. Tire Pressure, B. Tire Wear, C. Accuracy of 10 mile stretch

Example:

	Start	Finish	Total
Mile Marker	125	135	10 -- True Miles
Odometer	17154.5	17164.8	10.3 -- Odometer Miles

$$OCF = \frac{10}{10.3} = .9708737$$ Round off to .971

Speedometer Correction

Method:

1. Use individual mile markers found beside the road
2. Drive car at a constant MPH on the speedometer for 1 mile
3. Measure the time in seconds it takes to drive the mile
4. Apply formula

$$\text{True MPH} = \frac{3600}{\text{time (sec)}}$$

Example: Driving at 55 MPH on the speedometer it took 1 minute, 8 seconds to go 1 mile

$$\text{True MPH} = \frac{3600}{68} = 52.94 \text{ MPH}$$

5. If you want to know how long it should take to go 1 mile at a given speed, apply the following formula

$$\text{Time} = \frac{3600}{\text{True MPH}}$$

Example: How long does it take to go 1 mile at 55 MPH?

$$\text{Time} = \frac{3600}{55} = 65.45 \text{ sec}$$

NAME _____

150

ODOMETER & SPEEDOMETER WORKSHEET (5 points)

Car _____ Driver _____

Date _____ Tire Size _____ Tire Pressure _____

Road used for test _____

ODOMETER CORRECTION FACTOR

	Start	Finish	Total
Mile marker			
Odometer			

$$OCF = \frac{10}{\text{odometer total}} = \frac{10}{\quad} = \quad$$

Question: If you traveled 349.5 miles (odometer) on a trip and used 20.3 gallons of fuel (using your OCF)

1. How far did you really go _____ miles
2. What was your uncorrected MPG _____ MPG
3. What was your corrected MPG _____ MPG

SPEEDOMETER CHECK

How long does it take you to drive one (1) mile when your speedometer reads (do this in your car)

55 MPH _____ sec

30 MPH _____ sec

What is your true MPH when your speedometer reads

55 MPH _____ MPH

30 MPH _____ MPH

EPA/DOE
GAS MILEAGE GUIDE

The "Gas Mileage Guide" gives information on the relative fuel economy of cars and light trucks. The estimates are expressed in terms of miles per gallon as measured by the standardized EPA fuel economy tests. The first edition is published each year in September while the second edition comes out in February. A separation edition is published for cars sold in California. All new car dealers are required to have free copies available to the public.

VEHICLE CLASSES	LUGGAGE & PASSENGER SPACE
Two Seater	----
Mini-compact	less than 85 cu. ft.
Sub-compact	85 to 100 cu. ft.
Compact	100 to 110 cu. ft.
Mid-size	110 to 120 cu. ft.
Large	more than 120 cu. ft.
Small Station Wagon	less than 130 cu. ft.
Mid-size " "	130 to 160 cu. ft.
Large " "	more than 160 cu. ft.
Small Pickup	under 4,500 GVW
Standard	4,500 to 6,000 GVW
Vans	----
Special Purpose Trucks	----

The testing is performed to demonstrate compliance with the requirements of the Clean Air Act and the Energy Policy and Conservation Act. Each vehicle is tested under precisely controlled conditions by professional drivers in a laboratory on a chassis dynamometer. The dynamometer is a machine that permits exact simulation of the vehicle's operation under various driving conditions. Temperatures range between 60°F to 86°F.

Prior to 1979, vehicle results were listed for "city" and "highway" driving cycles and also a "combined" fuel economy figure was given. These numbers were usually higher than most drivers achieved in normal situations, so beginning in 1979 the Gas Mileage Guide gives only the results of the "city" test, calling it the "estimated mpg." However, both tests are still run and their results are used to compute the Corporate Average Fuel Economy (CAFE) figures that are required by the Energy Policy and Conservation Act of 1975.

CITY TEST (Estimated mpg since 1979)

This test simulates a 7.5 mile, stop-and-go trip with a speed range of 0 to 56 mph, and an average speed of 20 mph. The trip takes 23 minutes and has 18 stops. Eighteen percent of the trip is spent idling, such as would be expected in the city at traffic lights or in rush-hour traffic. Two kinds of engine starts are used. One is a cold start, which is similar to starting a car in the morning after it has been parked all night. The other is a hot start, which is similar to starting a vehicle after having parked it for a short time while shopping. The information from this test is then combined to represent the fuel economy of that vehicle during a realistic mixture of hot and cold starts during urban driving conditions.

HIGHWAY TEST

This test simulates a 10 mile, non-stop trip that begins with the vehicle warmed up. The trip has an average speed of about 50 mph and lasts 13 minutes. The speed during the test ranges from 0 to 60 mph. If your highway driving speed averages faster than the test's average of 50mph, you should expect to achieve poorer fuel economy than the highway fuel economy estimate in this Guide--about 10 to 15 percent less for every 10 mph above 50 mph.

EPA TEST CYCLE

	CITY (Estimated mpg)	HIGHWAY
DISTANCE	7.5 miles	10.0 miles
TIME	23 min.	13 min.
AVE. SPEED	20 MPH	50 MPH
RANGE	0-56 MPH	0-60 MPH
STOPS	18	0
STARTS	1 Cold 1 Hot	1 Hot

CORPORATE AVERAGE FUEL ECONOMY STANDARDS

PASSENGER CARS

1978*	18 MPG
1979*	19
1980*	20
1981**	22
1982**	24
1983**	26
1984**	27
1985**	27.5

*Set by Energy Policy and Conservation Act, December, 1975

**Set by Secretary of Transportation, June, 1977

LIGHT TRUCKS AND VANS
(up to 8500 lbs. GVW)

	2WD	4WD
1980***	16 MPG	14 MPG
1981***	18	15.5

***Set by Secretary of Transportation, March, 1978

Note: While the fuel economy figures found in the Gas Mileage Guide are now given in the city mileage figures only (since 1979), the CAFE standards still apply to the combined city and highway test procedure.

NAME _____

FUEL ECONOMY TEST

VEHICLE

Make _____ Model _____ Year _____

Odometer Reading _____ General Engine Condition _____

Engine Size/Type _____ Transmission Type _____

Tire Size _____ Tire Type _____ Tire Pressure _____

ENVIRONMENT

Date _____ Temperature _____ Wind _____

Location of test route _____

MPG ESTIMATE

What mileage do you expect to get? _____

What is the EPA mileage? Hwy ____ City ____ Comb. ____

DESCRIPTION OF TEST (What type of driving, what procedure, etc.)

TEST RESULTS

Miles traveled _____ Cost of gas per gallon _____

Gasoline used _____ Cost per mile _____

Calculated MPG _____

QUESTIONS

1. How did you measure the distance, was the odomter corrected?

2. What precautions did you use to obtain accurate fuel measurement?

3. What factors might explain a high or low result of your test?

166

FUEL ECONOMY

LOG

CAR _____

DATES _____ TO _____

155

167

DATE	ODOMETER	MILES	GAL	M/G	¢/G	COST	NOTES	DATE	ODOMETER	MILES	GAL	M/G	¢/G	COST	NOTE.

APPENDIX C

SLIDES

LIST OF FIGURES

Figure		Cited on Page
1.	Dynamometer	27
2.	Odometer with one tenth mile graduations	30
3.	Fuel being weighed on gram scale	33
4.	Auxiliary gasoline tank	33
5.	Hydrometer in gasoline sample	33
6.	Specific gravity of liquid apparatus	33
7.	Burette and small engine	34
8.	Fuel flow meter: SpaceKom Model 5100	35
9.	Fuel flow meter: Kent Moore Model J-22243	35
10.	Environmental Protection Agency fuel economy test in progress	36
11.	Weather measuring instruments	38
12.	Original Volkswagen used for "50/50 EEV"	54
13.	"50/50 EEV" engine	55
14.	Door design of "50/50 EEV"	56
15.	"50/50 EEV": April, 1974	56
16.	Original "Spirit of 76 MPG" Fiat and extra car for spare parts	60
17.	Hood design of "Spirit of 76 MPG"	60
18.	"Spirit of 76 MPG" Fiat: August, 1976	63
19.	"Bradley GT": August, 1976	65
20.	"Lancia Beta Coupe": July, 1977	65